# *Science in teacher training: Curricula in environmental science for colleges of education, with particular reference to the role of the physical science*

O'Donnell, Leo

# SCIENCE IN TEACHER TRAINING: CURRICULA IN ENVIRONMENTAL SCIENCE FOR COLLEGES OF EDUCATION, WITH PARTICULAR REFERENCE TO THE ROLE OF THE PHYSICAL SCIENCES

LEO O'DONNELL



MASTER OF EDUCATION THESIS 1969

CONTENTS

# CHAPTER ONE

## INTRODUCTION

In recent years there has been considerable curriculum revision in science teaching, both in this country and in others, at all school levels from primary schools to sixth forms in grammar schools. However, none of the bodies concerned with science teaching reform in this country, such as the Nuffield Science Teaching Project, and none of the national science study groups set up in the United States, has turned its attention to the teaching of science in establishments of teacher training, even though an examination of the suitability of teacher training courses seems essential, in view of the changes which have taken place in school science teaching.

The courses in Environmental Science outlined in this thesis have been developed to satisfy the changing needs of students in Colleges of Education, and because I believe that, in the past, these colleges have not attracted enough students into their science departments, particularly students of the higher ability ranges. Evidence is offered that College of Education students show particular weakness in the Physical Sciences, and so it has been thought desirable to pay special attention in this thesis to the part which the Physical Sciences ought to play in the science education of future teachers.

While courses of Environmental Studies have been quite common in establishments of teacher training for many years, the term Environmental Science is relatively new, and as there is no generally accepted definition of its meaning, one of the tasks of this thesis is to arrive at a clear statement of how I have interpreted it.

Since this thesis advocates science courses which are very broadly based, their value as scientific disciplines has to be justified, as there is still a considerable weight of opinion which considers a study in depth of a narrower field of science to be of greater value. The arguments advanced in the discussion of breadth versus depth are carefully considered. Courses in General Science, both for schools and colleges, have been advocated by many authorities, and over the years many schemes and syllabuses have been proposed, but in the main they have been neither popular nor successful, as I show in a later chapter. Narrower courses in single science subjects are generally preferred for older pupils and for students in colleges and universities.

It will be argued in this thesis that the courses in Environmental Science here proposed, do not suffer from the disadvantages of the General Science schemes and, moreover, that they afford a sounder basis of science for intending teachers than do the traditional university and college courses.

The way in which Colleges of Education organise their science departments is examined so that the courses which I propose will be constructed so that they are suitable, with local modifications, for adoption in most colleges. It is necessary to examine the qualifications and calibre of the College of Education students since they will be factors in determining the construction of the courses. A science department in a College of Education is required to provide several different courses, some for students who have studied one or more science subjects to Advanced Level, some for students who have hardly any science background at all, courses designed primarily for the personal education of the students, and courses aimed at equipping students to teach science in schools. The range of these courses and the needs they will have to satisfy are examined.

Since all students under discussion here are to become teachers in schools, the course of science study which they are to follow will be influenced by the science teaching methods they may wish to use later. Students should be made aware of the recent developments in science teaching in schools, primary and secondary, grammar, modern and comprehensive, and these developments are further factors to be considered in the preparation of the students' science courses.

A Main Course syllabus is outlined to show how a course which is very broad in its range, giving students a comprehensive view of science, can also provide adequate depth of study, by careful selection of interrelated topics. Since the syllabus alone does not convey the character of the teaching approach, one chapter has been devoted to a commentary on the syllabus.

When the curricula have been decided, or perhaps while they are being decided, the methods whereby the courses are to be taught require investigation. The amount and nature of the practical work, the value of field work, and relative proportion of time to be devoted to lectures, tutorials, and seminars, the possibility and desirability of team teaching, the place of students' personal projects, and the use of teaching aids, all provide topics for discussion.

A small number of students will be candidates for the degree of Bachelor of Education and the requirements of a science course to satisfy their needs is discussed. The curriculum courses will be attended by very large numbers of students whose needs are very different from those of main course and degree students. These needs of curriculum course students are examined and suggestions are made for suitable courses.

The opening discussion is concerned with the Colleges of Education, their courses and their students.

CHAPTER TWO

COURSES AND STUDENTS IN COLLEGES OF EDUCATION

In 1960 the length of the Training College course was increased from two years to three. There were two main reasons given for the extension, one being that it was felt that the majority of students were not being brought to full maturity in the two year course and without maturity it was difficult to teach well, and the other reason being that students were not being raised to a high enough level of general education. The report, "15 to 18", of the Central Advisory Council for Education (England) ( 16), - the Crowther Report - in 1959 had said:

> "The students in Training Colleges have often had too low a standard of general education both when they entered and when they left. The three year course should help here." ( 16.p.429).

Discussing the change of attitude in Training Colleges which followed the 1960 expansion, M.V.C. Jefferys, Director of the University of Bristol Institute of Education, wrote, in 1961, in "Revolution in Teacher Training" ( 45):

> "The Training College, historically rooted as it is in the normal school, has in the past been too much like an extension of school with a

vocational bias. It should be possible in the three year course to approximate the methods of study in colleges to the best practices in the Universities". (+45.p.32).

He looked forward to the Training Colleges making more use of tutorial work and less use of formal teaching methods, with the students being allowed more free time.

Two years later, in 1963, the Committee on Higher Education, in their report, "Higher Education" (+22) - the Robbins Report - concluded that the lengthening of the Training College course had improved the general education of the students:

"The teachers of the future will have had the opportunity to be better educated than their predecessors". (+22.p.108).

Because the character of the Training Colleges had changed since 1960, the Robbins Report recommended that the name should be changed to "Colleges of Education"- and this was done.

Since 1960 nineteen Colleges of Education have developed science "Wings" to help to relieve the pressing need for science specialists in secondary schools. As these "Wing" colleges have particular requirements and functions, they have not been included in the discussions which occur in this thesis which is concerned with the general three year Colleges of Education.

The prospectuses of Colleges of Education, the handbooks of Institutes of Education, and the lists of college courses published by the Association of Teachers in Colleges and Departments of Education and by the Department of Education and Science, show that the organisation of courses in most colleges conforms to a standard pattern. Students are engaged in one or two Main courses, a selection of Curriculum courses, a course in Education, and in several Teaching Practices. The responsibilities of a lecturer in a subject department were outlined by the Ministry of Education in a 1963 publication, "The Work of the Training Colleges" (+32) and in most colleges they remain the same now, (1969):

> "The three year Training College course consists concurrently of the students' personal education to as high a level as they can attain, together with professional training for teaching. Students study one or more "main" subjects ............ and also take minor courses in a variety of "curriculum" subjects.
>
> (+32.p.4).

"A subject lecturer will, therefore, usually be responsible for "main" and "Curriculum" courses in a given subject and will be concerned with the teaching methods used in presenting it, both in lectures and tutorials and in the students' teaching practice in schools". (+32.p.5).

Many colleges train teachers for schools with particular age ranges of children - infants, or juniors, or secondary schools, though more colleges are increasing their range, following requests from the Department of Education and Science. The National Advisory Council on the Training and Supply of Teachers, in 1962, prepared its eighth report, "The Future Pattern of the Education and Training of Teachers", and forwarded it to the Robbins Committee. This report gave the needs of the future teaching force and discussed the kinds of courses which the pattern of training would require. One of the main themes of the Committee was the need for flexibility in the teaching profession. It suggested that it was undesirable to train teachers for only one type of school, since in a career lasting forty years or more, many changes may occur and many new interests arise. It asked the question:

"What are the essentials of such a training system and what sort of teachers will provide the flexible and mobile adaptable teaching force we want? We believe these conditions will derive partly from the professional and partly from the academic side of the teacher's preparation". (+59.p.11).

The report goes on to examine the two sides in turn. It considers that a teacher will be more adaptable and more effective at any age level if he is prepared in training for as wide a range of teaching as possible. On the academic side it advocates the provision of courses at two levels, one for the "specialist" and one for the "general" teacher. It recognises the considerable ability range of the students and suggests that, in addition to the course at the two levels already proposed, general degrees of a different character from those already offered by the universities should be provided.

The wide range of student ability has been recognised also by the Robbins report and by the Central Advisory Council for Education (England) in their 1967 report, "Children and their primary schools" (+18) - the Plowden report, which gave a more precise definition to this variation:

"We are advised that there is a wide variation in the standards attained by students in the

> main courses. The best already reach the level of an ordinary degree, but at the other end of the scale are students who pass at a level little beyond the Advanced level in General Certificate of Education examinations". (+18.p.344).

Since the report does not criticise this situation, one is left to assume that it is acceptable, provided an attempt is made to educate each student to as high a level as possible.

There appears to be general agreement that there are three requirements of a main course, to assist in improving the educational level of the student, to develop maturity in the student, and to prepare the student for the teaching of his main course subject. This third requirement is sometimes disputed by those who maintain that only curriculum courses should be directed towards the teaching of a subject, but there is clear indication in "The Work of the Training Colleges" (+32) that the Ministry of Education intended that the main course should have a vocational value as well as an educational one:

> "The student must have maximum freedom of choice, though he may also need guidance, in the selection of his main subject(s). But this freedom cannot be absolute, for the student is being trained for

a career of teaching in schools. It follows that the needs of the schools must influence the training given." (+ 32.p.3).

It is, of course, difficult and unnecessary, in practice, to keep these three aims separate, but in preparation of the main course they must all be kept in mind.

There is a danger that main courses may become unimaginative extensions or even repetitions of work done in sixth forms at school. Appendix Two (B) of the Robbins report contains some opinions expressed by Training College students:

"Many students in teacher training, as in universities, reported that they had "repeated at college some of the subject matter which they had already covered in the same way at school". Of students in the second year or later, 61% reported that they had done so, compared with 51% in universities.........
Of the students who had taken examinations at the end of the first year, over half (53%) considered that they could have passed the examinations while at school." (+ 22.p.82).

This highly undesirable state of affairs must be avoided when main courses are offered to students, but it will not be easy to avoid some repetition for some students in those departments, for instance in science, where there is considerable variation in the previous subject experience of the students.

The introduction of the Bachelor of Education degree into Colleges of Education has provided subject departments with an additional commitment. Degree candidates will spend four years at college and in that time they will, generally, study two main course subjects in addition to Education. While the total time which a degree student will be able to spend on any one main course subject will probably be no greater than that which a certificate student can spend, the degree student will have to show evidence of having studied at least part of the subject to a greater depth than the certificate student. Separate courses will have to be provided for degree and certificate candidates in a main course subject, though the Robbins report does suggest that it might be possible to have an initial common course for all students and to divide them later into "degree" and "certificate" classes. (+22.p.115) The proportion of students attempting the degree course in Colleges of Education in the early stages is small, less than ten per cent, though the estimate given by the Robbins Committee of the maximum demand in the middle '70's is twenty five per cent. Colleges training teachers for primary schools would offer the Bachelor of Education degree in the same way as for other colleges. On this point the Robbins report says:

> "We hope that as universities, institutes of education and colleges come into closer contact, ways will be found of reconciling high academic standards in the B.Ed. course with relevance to primary education." (+22.p.346).

Many teachers are called upon to teach subjects other than those they studied in main courses, and "curriculum" courses are provided to assist students to prepare for this situation, which is particularly common in primary schools. In some colleges these courses are known as "method" courses, though in others the term "method" has a different and much narrower meaning. There is evidence in official publications that curriculum courses are not intended to be merely courses of instruction in classroom techniques. The Robbins report says:

> "In their curriculum courses students study the content of subjects but they also consider examples of children's work, and discuss the ways

of teaching these subjects and of overcoming the learning difficulties that pupils are likely to experience." (+22.p.223).

And the Plowden report:

"Curriculum courses, intended to inform students both about the subject matter that children will learn in school and the way they will learn it, are essential." (+18.p.346).

In colleges preparing students for primary schools the curriculum course receives greater emphasis. While there is considerable variation between colleges in the nature of curriculum courses - in some colleges there is little, if any, "method" taught - in general there is a distinct vocational purpose in courses of this type.

In preparing our courses in Environmental Science, then, we shall need to take care that:

(a) the main course is one that not only raises the personal education of the students to as high a level as possible and gives them the opportunity for some study in depth, but enables them to teach the subject to some degree of specialisation,

(b) the curriculum courses are capable of giving to students with a very wide variety of science background, including some with no background at all, sufficient knowledge of the subject and the way children learn it, together with the confidence necessary to handle the material, living and inanimate, which they will need to use,

(c) all our courses are flexible enough to allow our students to use them, in years to come, as bases for extension beyond the age range for which they were originally intended,

(d) all our courses allow sufficient variation for individual students of different abilities to benefit from them, so that none will be bored by repetition but none will be forced to move at a pace beyond his capability,

(e) the course we provide for our abler students, the Bachelor of Education course, has the necessary ingredients of a true academic discipline of a standard equal to that of a university.

In order that we may estimate the academic standard of the course in science which we propose to offer to the students we shall have to look at the students' qualifications and the amount of time they will have to devote to the main course and curriculum course studies.

Appendix Two (B) of the Robbins report gives some tables of qualifications of students entering Colleges of Education in 1961. These, when compared with figures given for the 1965 entry in the Department of Education and Science's Statistics of Education, show that, during the expansion of the colleges, there has been some improvement in the level of qualifications.

TABLE 85 OF THE ROBBINS REPORT (+22. p. 76)

Number of 'A' levels held by students on 3-year courses.

| 1961 (percentages) | 3 or more | 2 | 1 | 0 |
|---|---|---|---|---|
| Men | 18 | 24 | 27 | 31 |
| Women | 12 | 22 | 23 | 43 |
| Men and Women | 13 | 22 | 24 | 41 |

TABLE 3 OF STATISTICS OF EDUCATION (+34. p. 129)

Number of 'A' levels held by students on 3-year courses.

| 1966 (percentages) | 3 or more | 2 | 1 | 0 |
|---|---|---|---|---|
| Men and Women | 13 | 24 | 25 | 38 |

It is seen that, despite the expansion, the percentage of those with three 'A' levels or more remained about the same, and the percentages of those wiht one or two 'A' levels increased; the increase in numbers did not lead to a lowering of entry qualifications in terms of 'A' levels. About forty per cent of students entering Colleges of Education have the minimum qualifications for entry into university, though, of course, this does not mean that they would have gained entry had they applied. In fact, several of them will be students who would have preferred to go to a university but failed to gain admittance. As the Robbins report points out, however, there are students in Colleges of Education who could have gone to a university but chose not to:

> "But there are others, and especially youg women, who know when they are still at school that they wish to become teachers and who, other things being reasonably equal, would prefer a course of combined education and professional training to a university degree course. Among these are students who certainly could do well in a university degree course of the present type."
> (+22.p.107).

At the other end of the scale, as Table 87 of the Robbins report shows, fifteen per cent of the students entering

Colleges of Education in 1961 had only five 'O' level passes as their entry qualifications. The 1966 Statistics of Education show that the percentage with only five 'O' levels had fallen to eight per cent. These figures of general qualifications show that we must expect to find a wide ability range among the students on our courses.

When we examine the statistics provided by the Robbins report on the science qualifications of College of Education students they present rather a disappointing picture, particularly if we compare them with science qualifications of university students. Table 93, p.82 and Table 31, p.27, show the percentage of the student population qualified at 'A' level in science subjects (including Mathematics), and these are further broken down into Physical Sciences and Biological Sciences. The figures are:

| | UNIVERSITIES | | | COLLEGES OF EDUCATION | | |
|---|---|---|---|---|---|---|
| | Science | Phys. | Biol. | Science | Phys. | Biol. |
| Men | 61 | 41 | 20 | 41 | 23 | 18 |
| Women | 36 | 14 | 22 | 20 | 7 | 13 |
| Men and Women | 54 | 33 | 21 | 27 | 12 | 15 |

More than half of all university students are qualified in science subjects and one third of them in Physical Sciences. In the Colleges of Education only a quarter have their 'A' levels in science subjects and only one eighth in a Physical Science. These figures, we must remember, relate only to students with 'A' level qualifications, and about one third of the students in Colleges of Education have no 'A' levels at all. It might be thought that the universities take a much larger fraction of Science sixth form pupils than Arts sixth, so leaving a bigger Arts sixth fraction for entry to Colleges of Education. However, the figures of 'A' level passes of Examinations Boards show that this is not true. For instance, in 1961, the year examined by the Robbins report, 50% of all 'A' level passes in the General Certificate of Education were in science subjects, (+34,Pt.three, p.13) and the percentage of university students who had been in science sixth forms was 52%, (+22, App. Two (B), p.28). Since 1961 both these percentages have gradually fallen, but have remained more or less equal to each other. We must conclude that a substantial fraction of pupils qualified in science at 'A' level do not consider coming into Colleges of Education, leaving the colleges heavily weighted on the Arts side.

The Robbins report gives us useful information about the 'O' level science qualifications of students in Colleges of Education and some of it is relevent to our discussion. Table 95, p.84, in Appendix Two (B) tells us that the percentages of students with an 'O' level pass in a science subject other than Mathematics are: Men 66%; Women 72% and Men and Women 70%. The importent feature here is that 30% of our students have no 'O' level pass in any science. It is also fairly certain that the science pass for many of the women students will be Biology, since the pattern for girls at 'O' level is similar throughout the country and the Joint Matriculation Board figures show that the percentage of girls 'O' level passes in Biology is 50.9% of all science passes gained by girls. (+47. Table 3).

A very disturbing feature, from the point of view of the Physical Sciences, is the fact that only 53% of all women students have an 'O' level pass in Mathematics; it sounds even more disturbing put the other way round - very nearly half the women students have not passed Mathematics at 'O' level. For men the pass figure is 82% and the overall figure for men and women together is 61% pass. In view of these figures it is perhaps not surprising, though very disappointing, to discover from Table 17 of Appendix two (B), p.228, of the Robbins report, that the number of College of Education students engaged in main course science subjects is very small and in particular that the Physical Sciences are sadly neglected. Table 17 gives the percentages of students on three year courses in all main course subjects and from this the science subjects have been selected;

| PERCENTAGES OF ALL STUDENTS IN MAIN COURSES | | | |
|---|---|---|---|
| | Men | Women | Men and Women |
| Mathematics | 19 | 9 | 12 |
| General Science | 7 | 2 | 3 |
| Physics | 10 | 2 | 5 |
| Chemistry | 6 | 2 | 4 |
| Biology | 8 | 12 | 11 |

Table 18,p.229 of Appendix Two (B) of the Robbins report shows that the larger colleges teach science to a much higher proportion of their students than the small colleges, where the science is often Biology only, but even the colleges teaching most science do not have a total percentage of science students greater than 35 per cent.

The Dainton Report, (+36), an enquiry into the flow of candidates in science and technology into higher education, showed in Table 6, that while the percentage of school leavers with one or more G.C.E. 'A' level passes entering Colleges of Education between 1961 and 1965 remained fairly steady, between 15 and 17 per cent, the proportion of these entrants who had specialised in science subjects for 'A' level, already small in 1961, only 16 per cent, (1300 students), had fallen by 1965 to 13 per cent, (1600 students). The numerical rise of the student number from 1300 to 1600 must be considered in relation to the rise of total school leavers with one or more 'A' levels from 49000 in 1961, to 83000 in 1965.

Figure 5 in the same report shows that the percentage of the first year sixth form science population has decreased steadily from 44% in 1962 to 33% in 1967, though the science picture is slightly improved by the growth of mixed Arts/Science sixth form groups from 10% in 1962 to 15% in 1967. These Dainton report figures indicate that for some years to come we can expect the proportion of science students entering Colleges of Education with 'A' level science qualifications to decrease, and the opinion is expressed in the report that competition with other sectors of higher education for such pupils may become even more acute.

Important factors contributing to the success or failure of a student's course are the attitude of the student and the incentive provided for him. These would be difficult to measure and display statistically but the Robbins report mentions one point which is worth emphasising:

> "For many students, too, a strongly felt professional purpose is a great incentive to the education that ... should accompany training in a liberal profession. That is something that the colleges have learned to turn to advantage. For example, a young women with no great desire to take a degree in psychology but with a genuine interest in children may study their psychological development with an enhanced sense of relevance when it is combined with observation of children in school and practice in her future vocation. (+22.p.107).

When our students, visiting and working in schools, see children interested in science, perhaps they themselves will become more willing and eager to follow science courses in college. The Crowther report, earlier, had also pointed out the value of using the vocational incentive:

> "... experience both in this country and in Germany seems to show that vocational content

gives students a sense of reality and purpose".
(+16.p.178).

When we consider the amount of time which students have available we find that there is considerable variation from college to college in the distribution of time between main, curriculum, and education courses. There are many colleges which at present train students for schools of one age range and it is customary for primary school colleges to devote a relatively large proportion of time to curriculum courses and to require only one main course, whereas secondary school colleges very often ask for two or even three main course subjects and the time given to curriculum studies is small. It has already been said that the training of students for a narrow age range is not desirable but there will always be some variation in preparation for older and younger children. We can only provide for the average situation and this can be judged from two tables given in the Robbins report. Table 14, p.224, Appendix Two(B) shows the percentage allocation of time in Teacher Training Colleges.

| PERCENTAGE ALLOCATION OF TIME | | | | |
|---|---|---|---|---|
| TYPE | MAIN | CURRICULUM | EDUCATION | PRACTICE |
| Primary | 38 | 31 | 17 | 14 |
| Secondary | 52 | 17 | 17 | 14 |

Table 15, p.226, Appendix Two (B) shows how many main course subjects students take:

| | PERCENTAGES | | | |
|---|---|---|---|---|
| | THREE | TWO | ONE | NONE |
| Men | 7 | 51 | 42 | 1 |
| Women | 6 | 34 | 57 | 4 |
| Men and Women | 5 | 41 | 51 | 3 |

If we assume that in general the secondary college allocation of 52% of its time to main course covers two subjects and the primary colleges 38% is for only one main subject the average figure for percentage time available per main course subject lies between 26% and 38% and could be said to be about one third of the college time. In most colleges main course studies are for three years. Examples from the Handbook on Teacher

Training (+7) indicate that the number of curriculum courses is rarely fixed and that it is usually at least two but could be five in primary colleges, and is usually only one in secondary colleges. The time allocation, on a rough average, per curriculum subject could be taken as about 15%. In most colleges, curriculum courses last one year. The Robbins report gives the average College of Education year as 35 weeks and the average week as 16 hours (Appendix Two (B) p.295). On this basis the time available for a main course subject would be about 180 hours in each of the three years, and for the curriculum course about 80 hours for one year.

The plans for Bachelor of Education study so far published by the Institutes of Education arragne for students to take, usually, two Main Course subjects plus Education in their examinations, and the course is to last for four years. As it is also assumed that the time given to curriculum courses by B.Ed. students will be less than that given by Certificate students, the general conclusion is that the total time available for each subject of main course study for B.Ed. candidates will be about the same as for Certificate students, that is about 540 hours total, in the four years.

Having examined the organisation of College of Education courses, the qualifications of the students, and the time at their disposal, we must now outline the characteristics of the science courses which we wish to have in these colleges. These courses will differ from the school courses to which the students have been accustomed in several respects. As the adolescents pass into maturity they should be required to accept a greater responsibility for their own work and there should be much more freedom for the student in college courses than one would expect to find in a school. Not all students will cover the same ground in our science courses, which should be flexible enough to allow students some choice, not only in subject matter but in time allocation to the several parts of the course, as well as to the depth which individual students are expected to follow particular topics. Many of the students will have studied eight or more subjects to Ordinary level of G.C.E. and some of these will have been studied primarily for the acquisition of the Ordinary level pass in order to qualify for college entry. It is hoped that our college courses will not be looked upon as examination subjects for a teacher's certificate, and that we shall provide satisfying and sustained incentives to our students.

The College of Education courses in science will also show marked differences from those in universities. It is to be remembered that while science undergraduates are usually concerned only with the study of science, and very often only one specialised section of it, all College of Education students are involved, at the same time, with study of the theory and practice of Education, with a variety of curriculum courses, with teaching practice, and sometimes with a second main course. One result of this division of concentration is that it is essential that the aims of the science courses be clearly defined to the students and that the overall structure of the courses be obvious to them. If the relationships between the science courses and the rest of the work which a student is doing are not clear he will fail to derive full benefit from these courses.

We should mention here the particular problems of the B.Ed. students, at least in these early years of these degree courses. The B.Ed. courses ask a standard of academic work equal to that required of the university undergraduate, but the B.Ed. courses are often in a very small minority in a College of Education where the climate of study is not as academic as one finds in a university.

That the average intellectual ability of students of Colleges of Education is lower than undergraduates we have seen earlier in this chapter, but there are other considerations affecting the principles on which we are to build our courses. Some universities science students will be required, after they graduate, to enter fields of research which are trying to extend the frontiers of scientific knowledge, and undergraduate courses are designed partly to lead on to post-graduate work. College of Education courses, on the other hand, must be complete in themselves. The vast majority of students taking our science courses will receive no further science training for the rest of their lives. We must be sure that the picture of science that we paint for our students is as balanced as possible.

Above all, the courses that we construct must be suitable for teachers. The factual content of the work is much less important than the way in which our students are led to find out information and the way they use the information they have found. It is very important that our intending teachers should understand thoroughly whatever science they are studying. What they learn they should learn well enough to remember and use in their teaching. While the science selected for study should not be determined because of narrow vocational demands, due consideration should be given to its suitability for a future teacher. The common practice in universities of giving the same course in science to intending teachers and to future technological specialists seems to me to be open to considerable criticism.

In many cases, particularly with students intending to teach in primary schools, the factual content of the science main course will not be used in subsequent teaching, and if the course is not constructed to be, of itself, intellectually satisfying to the students, there is danger that their interest will fade. There must be an emphasis in the course on kindling and maintaining curiosity and enthusiasm and this will be done, at least in part, by ensuring that the students become involved in personal investigation of sufficient depth to satisfy them.

Science course in universities can be constructed with the knowledge that most of the students, if not all of them, have a common basis, of a recognised level, on which the course can be built. A physics course, for example, can assume that all students have an Advanced level pass in Physics, and in many cases a minimum grade can be insisted upon. As time goes on, there will be of course, a growing spread of achievement. A College of Education Science department, however, running an integrated science course, has no common qualification which it asks of all its students. It might require some Ordinary level science passes, or perhaps one or two Advanced level passes, but they will be in a variety of different sciences in any group of students. Passes at eitherlevel in Physical sciences will be in short supply and there will be serious deficiencies in mathematical ability. To satisfy this wide range of backgrounds our courses will have to have built into them, flexibilities of both content and method. For the majority of the college population the science department will be trying, through its curriculum courses, to make science a simple, attractive, reasonable and worthwhile study, which can be used as a basis for investigational work in schools.

The priorities for our college courses can be summarised.

1. A main course, accepting students with only moderate science backgrounds, and on the average, weak mathematics, which gives an accurate picture of the scope and methods of science, and which attempts to redress the balance which exists against the physical sciences.

2. A Bachelor of Education course, in which the place

of science in education is recognised, and which offers to the best students all the intellectual satisfaction of a university course.

3. A large number of curriculum courses which will extend to as many of the students in the college as possible, and in which all students are given familiarity with, and confidence and interest in the ways in which children of all ages can be encouraged to develop their natural instincts for investigation.

CHAPTER THREE

SCIENCE IN THE SCHOOLS

Most students in Colleges of Education have come from grammar schools, but quite a number were for some or all of their time at modern schools, while a few have been at comprehensive schools. We shall need to examine, in this thesis, the science background which our students have brought with them from these secondary schools. In recent years there has been considerable activity in the field of science teaching for all types of secondary schools and we shall have to estimate how changes proposed in content and methods of teaching will be implemented in the schools, since some of our students will be going back to these schools as teachers. Others of our students will, however, be going into primary schools, where also there have been proposals for changes in science teaching, so our discussion will also have to cover the field of primary school science. Since many of the schools throughout the country are involved in a system of reorganisation and since we have said that our teacher training system should be flexible enough to allow teachers, over the years, to move from one type of school to another, we shall have to discuss with all our students the ideas about science teaching in secondary and primary schools which are currently being debated.

Let us begin with the secondary schools, partly because more publicity has been given to this area than to others, and partly because science teaching began in these schools. As most of the schemes for curriculum changes in science have been published since 1960, this would seem to be a suitable point in time at which to consider the characteristics of science teaching in these schools as a basis for discussion.

At the end of 1960, as the figures given in Appendix A of "Education in 1961" (+31) show, there were three times as many modern schools as grammar schools in this country, the number of technical schools had fallen to one sixth of the number of grammar schools, and the comprehensive schools also were about one sixth of the grammar schools. The ratio of children taught in modern, grammar, technical, and comprehensive schools were 34, 14, 2 and 4 respectively. The actual figures are given in the following table: (+31.p.36)

| | SCHOOLS | PUPILS | TEACHERS |
|---|---|---|---|
| L.E.A. | | | |
| Modern | 3872 | 1698379 | 75171 |
| Grammar | 1284 | 696677 | 36927 |
| Technical | 228 | 97039 | 5096 |
| Comprehensive (all types) | 200 | 186065 | 9236 |
| Others | 263 | 150815 | 6974 |
| DIRECT GRANT | | | |
| Grammar | 178 | 110108 | 5935 |
| Technical | 5 | 833 | 53 |
| INDEPENDENT | 435 | 87466 | 6411 |

The ratios of the teachers in the different schools was about the same as the ratios of the pupils, but whereas 75% of grammar school teachers were graduates, only 16% of modern school teachers had degrees. (+31).

Our attention will mainly be directed towards the science teaching in grammar schools and modern schools since the comprehensive schools had not, at this time, developed their own science outlook, and the technical schools have since been or soon will be, absorbed in the new reorganisation.

In most grammar schools, science was being taught in 1960, as separate subjects of physics, chemistry and biology, except perhaps in the first and second years, where a form of general science was often taught. The official view expressed in the Science Masters' Association publication for grammar schools, "The Teaching of Science in Secondary Schools" (84) was that General Science was less adequate than separate sciences for later advanced courses. (+84. p.129).

The syllabuses throughout grammar schools were almost universally those of the examinations boards, and the influence of the universities, which was most evident in the Advanced level G.C.E. syllabuses, was also very strong at Ordinary level, and this in turn determined much of the rest of the school syllabus. (+83, p.x.). Boys'schools emphasised the teaching of physics and chemistry and girls' schools biology, and this state of affairs has shown little improvement in the years between 1960 and the present (1969), which unfortunate situation will be discussed in a later chapter. Most grammar schools taught by the same standard method which the Crowther report called "academic" and summarised as:

" ... first expounding the principle and then illustrating it, by teaching the rule and its exceptions, and then setting the class to work on examples." (+5, p.394).

The prevalence of "the purely logical approach" in science teaching was commented upon, with disapproval, by the Science Masters' Association, which admitted that many teachers were reluctant to change. (+84, p.132). Lessons were prepared beforehand in detail and a lesson was considered to be a good one if it achieved exactly what it set out to achieve in exactly the right time. All pupils in a given class tended to do the same things at the same time, and digressions, whether introduced by the teacher or the pupils were not considered advisable. (+84, p.135).

One feature of science teaching in schools of which we, in this country, were traditionally proud was the amount of practical work which the pupils carried out themselves. (+29, p.36). Some teachers from other countries envied us our system, while others criticised the nature of this practical work, saying that it was tedious, repetitive, and time wasting. Generally speaking, because of this emphasis on practical work, grammar school laboratory facilities were quite good and many of them had laboratory assistants or technicians.

The picture in the modern schools was, on the whole, rather different. Whereas most grammar school pupils, according to the Science Masters' Association, (+83,p10), studied science subjects to obtain some qualification which would be useful to them in a future career, modern school children did not primarily look to their science for a qualification, though over the years more and more of them entered G.C.E. and later C.S.E. examinations. The pattern of science teaching varied from school to school much more in modern schools than in grammar schools, partly because the C.S.E. Mode Three form of examining, whereby schools submitted their own syllabuses, allowed some flexibility, and partly because the purpose of the modern school, even in 1960, was not as clearly defined as that of the grammar school, (+83,p.x), and the nature of the incentives which should be offered not obvious. It was much more common to see General Science being taught in modern schools than separate subjects, and many variations, such as Rural Science, Gardening, and B eekeeping, were also well established.

Modern schools rarely kept their pupils beyond the age of sixteen and in many of them the majority of pupils left at fifteen and this narrow age range, compared with the grammar schools, had a considerable effect on the syllabus, since it had to be complete in itself by the age of fifteen. The two other features affecting the syllabus and the teaching were that the standard of reading and writing ability in modern schools was below that of the grammar schools, and that the amount of homework was considerably less and in some schools was not set at all. While there was ample opportunity for adopting and approach to science teaching very different from the academic style of the grammar school, more often than not the same approach was used. (+79,p.3).

The Science Masters' Association had never been able to claim a large number of modern school teachers, but it had produced in 1957, "Secondary Modern Science Teaching", (83), and there was a serious attempt to get away from the traditional grammar school method, but the Association later admitted, (+4,p.xi), that it had not really succeeded. However, this was the first publication by an authoritative body which questioned many of the well established traditions of science teaching, in that it advocated an emphasis on the way knowledge was collected rather than on the knowledge itself, on investigation by the pupils rather than verification, on the desirability of opportunism and purposeful digressions, and on a more flexible method of teaching.

In some individual modern schools and in some groups of schools, considerable success was achieved in formulating coherent and attractive schemes of science teaching. One such scheme was developed in Manchester by a committee of representatives from the modern schools, training colleges, and the local inspectorate, and published in 1957 as "Teaching Science to the Ordinary Pupil", by Laybourn and Bailey, (51). This scheme laid emphasis on the pupils' own experience, on a very wide treatment ignoring subject boundaries, on dealing primarily with objects and only secondarily with principles, and on careful observation of practical situations.

The Secondary Technical Schools proposed by the 1944 Act did not grow in large numbers but they did develop an attitude towards the subjects they taught which is well worth remembering. The technical bias which they gave to their science courses is not an end but a means, and they use the obvious link between the school subjects and industry and commerce to give a stimulating incentive to their pupils. Reece Edwards, in his book, "The Secondary Technical School," (+35), quotes the aims advanced by several technical school headmasters, and there is unanimous emphasis on the need for a purpose obvious to the pupils in all that is done, a purpose which is not always clear in the traditional academic approach.

Not since 1932 had any document concerning the teaching of science been issued by the Ministry of Education until, in 1960, the pamphlet No. 38, "Science in Secondary Education", (+29), was published. The first point of interest, and it is a significant one, is that its discussions and recommendations were intended for the attention of both grammar school and modern school teachers, and nowhere in the book is any distinction drawn between the way in which science should be taught in the two types of school for children up to the age of fifteen. The members of Her Majesty's Inspectorate who produced the book used experience gained in 98 modern and 54 grammar schools, (+29,p.28). Apart from the lack of distinction between different types of schools there were many innovations suggested in the pamphlet, which, strangely enough, does not mention technical or comprehensive schools at all.

The teaching of General Science to all pupils in all schools up to the age of fifteen was advocated, (+29,p.40), and it was argued that this was good not only for the non-specialists whose science education was to end at fifteen or sixteen, but also for those who would go on to study separate subjects after they were sixteen. The separation into specialist science subjects at sixteen was strongly defended and it was claimed that one of the best features of English schools was the opportunity given to older pupils for quite extensive study in relatively narrow areas within the science subjects. (+29,p.27). Strong emphasis was laid on the need for a balanced science curriculum of both physical and biological sciences for all pupils of both sexes up to the age of fifteen and also beyond that wherever possible, and the practice of segregating pupils at thirteen or fourteen according to their chosen careers into arts and science specialists was deplored.

On methods of science teaching the pamphlet said that insufficient use was made of the natural curiosity and interest of the pupils and a more empirical, practical approach was advocated. Realising that this suggested approach would mean slower progress and that time would have to be saved somewhere else, it was suggested that good demonstrations could be substituted for much of the traditional practical work which was often largely concerned with verification of laws or determination of constants. The inspectors anticipated the criticism that what was being advocated was "no more than General Science taught by heuristic methods which are unsatisfactory and out of date", but this criticism they refuted, saying that what they wanted was for each pupil to be faced with a problem to investigate two or three times in his career before the age of fifteen. Unfortunately the Schools Council had to report, some five years later, that the impact of the Ministry pamphlet and of the Science Masters' Association publications in schools had been "a good deal less than might have been hoped". (+79,p.2).

In 1961 the Science Masters' Association issued a "Policy Statement", (+85), concerning the teaching of science in grammar schools and this was to prove to be the first step in a series of moves which were to have a considerable influence on science teaching, not only in grammar schools but in schools of all types. The basic theme of the statement was that science education should be considered a cultural necessity for evryone and that there should be no competition or antagonism between arts and science eduaction at any level. They followed the line of the Ministry suggestions that there should be no subject specialisation before the age of fifteen or sixteen, that is to about Ordinary level G.C.E. or C.S.E., that up to this age all pupils should be involved in both physical and biological sciences, that some science should be taught to all pupils after the age of sixteen, and t hat the factual content of all science courses should be reduced in favour of more observation and discovery by the pupils. The statement did not support the Ministry policy, however, when it maintained its plan of General Science for only two years folowed by three years of separate physics, chemistry, and biology courses, and by suggesting different courses for grammar schools and modern schools. There should be, it suggested, a considerable change in emphasis in the way the sciences were taught. Experiment as a means of discovery was to be the basis of all courses and practical work should lead to the formation and testing of hypotheses.

The separate subject sections of "Science and Education" published with the policy statement took up the general principles as they applied to the particular subjects. For instance, physics teaching was said to be out of date and was slanted too much towards the needs of the future specialist. (+86,p.4).

The aim was repeated as "Physics for all" not "Physics for the future specialist". Above all, said the physicists, a new system of teaching which would encourage the pupils to "think" in a commonsense way about physical topics was needed.

To help teachers to bring their physics teaching up to date the Science Masters' Association in conjunction with the Nuffield Foundation published in the following year, 1962, "The Teaching of Modern Physics" (87), a comprehensive guide which was welcomed by a large number of physics teachers.

In 1962 the Nuffield Science 11 - 16 Teaching Project began its preparations and school trials, which resulted in publication in 1966 of complete courses in physics, in chemistry, and in biology for grammar schools and the top streams in modern schools for children from eleven to sixteen. Our students should be aware of the conclusions that the Nuffield Project has arrived at, and of the areas where further research has been indicated. The Nuffield programme has been produced in three separate subjects and this would appear to support the traditionalists against those who favour an integrated course, but this is not entirely true. In 1964 the Nuffield Progress Report (67) announced the beginning of work on a Combined Science scheme and suggested that the separation of school science into three branches was, educationally, perhaps not the best way of presenting them. The reasons given for adopting a three subjects plan were the need for speed and the desire not to introduce too many innovations at the same time.

To find out how the programme of the Nuffield Project differs from those suggested by other organisations in this country, in the United States, and in Europe, we must look at the approach rather than the content. The central objective is "Science for all" as it was in the Science Masters' Association policy, science not just for the future specialist but for the future citizen, and particularly for the rather distant future citizen. The scheme is an attempt to use the natural excitement of children and to bring them to understand what science is and what it is like to be a scientist, by their own investigations, problem posing, and solving, and their own arguments. This is to be done by providing a course of science which will not only be a discipline in its own right but one which will encourage an attitude of critical enquiry, and an ability to collect evidence, to evaluate the validity of conclusions and to assess their importance. A primary aim is to achieve an understanding deeper than the mere recalling of what the pupil has been taught to recall and this requires a change in approach to the subject.

The Project organisers were aware that many teachers would find legitimate objections to such an argument and they anticipated three of them in their initial report. Teachers would be unfamiliar with this approach and apprehensive of the difficulties they foresaw in its adoption; teachers, while believing in the ideas proposed, would believe that the burden involved in carrying them out would prove too heavy; teachers would feel that the present educational system would not allow enough time to carry out the programmes effectively. It was agreed that the teachers would find the scheme demanding, as would the children also, but justification for the scheme was that the rewards for both teacher and pupils, interms of greater sense of excitement and discovery, were well worth the price. The hope was that the children, instead of always being provided with ready-made answers in the classroom and complete and precise instructions in their practical work, would have the opprtunity to think and reason for themselves when prompted by searching questions, and would be required to carry out investigations of their own design, and so they would learn by their mistakes and be encouraged by their successes.

The Nuffield organisers set about the difficulties they anticipated in three ways. In order to help the teacher to overcome his apprehension they provided teachers' guides which covered all aspects of the course in complete detail. They provided a course which was a carefully planned concentric approach and in which the new work was gradually introduced and brought back in later stages with increased sophistication. They reduced the time pressure by omitting quite extensive areas of traditional school science material and by providing more effective new apparatus for pupils to work with and for teachers' demonstrations.

Two areas in particular are seen to be very different in the Nuffield schemes from the traditional schemes, the nature and use of practical work, and the type of examinations employed. In traditional schemes much of the practical work consists of verifying what has already been dealt with theoretically or of carrying out measurements according to instructions carefully prepared. In the Nuffield programmes the practical work is, to a considerable extent, the source of information for the pupils. The apparatus provided is often suited to "open-ended" experiment, that is, it enables children to gain information or evidence from more than one direction and without a specific goal in mind. Much more apparatus is called for by Nuffield and there is greater emphasis on each child working on his own and at his own pace. In the introductory stage, and all three programmes, in physics, in chemistry, and in biology, contain such an introductory stage lasting two years, the pupils are encouraged to spend quite some time in observing closely and considering carefully their familiar surroundings. Later the results of these observations are examined more analytically and the quantitative nature of the work increases.

It was recognised from the beginning that if the Nuffield proposals were to succeed, a completely different type of examination would be needed. As the programmes covered the years eleven to sixteen it was imperative that agreement should be reached with the Examining Boards and this agreement has resulted in Ordinary level papers of the G.C.E. being made available to all who need them, prepared in the Nuffield idiom. The setting of these "Nuffield" questions requires a different outlook on the part of the teacher and study of the books of questions for homework, for tests, and for examinations, is one of the tasks facing all who may be called upon to take up the teaching of a Nuffield programme. If the questions are to test the pupils' understanding of a science subject and not merely his aptitude for recall then they must be carefully prepared so that the pupils will realise that only by careful thinking will they be able to answer them. These questions are difficult to devise and their preparation is a serious problem for our future teachers.

There is a danger that the Nuffield programmes may be looked upon as a new orthodoxy, as the right way to teach science. John Maddox, the Director of the Nuffield Project, stresses the need for constant change:

> "Teachers themselves will wish to make changes. Sooner or later there will have to be another programme to produce another O level physics course, for the curriculum must be dynamic if it is to stay alive." (+ 55,p.7).

It is important that we should impress this outlook on our students lest we give them the impression that they are searching for a complete and lasting programme of science teaching.

Our students must also know that proposals like the Nuffield programme are not received passively by all teachers. The teachers concerned with trials and those who have the Nuffield ideas on in-service courses have often criticised all or some of the proposals. Articles by trials teachers of physics, chemistry, and biology have appeared in the Journal of the Institute of Education of the University of Newcastle upon Tyne under the general heading, "Teaching the Nuffield Way", (+ 100). All the contributors to this series have had criticisms of the particular schemes in which they were involved, though not surprisingly they do not always agree among themselves, but it apparant that all of them have accepted much of what was new with considerable enthusiasm. It has been my own experience while conducting Nuffield in-service training courses that while many teachers bring with them some suspicion and apprehension, much of this rapidly evaporates and is replaced by a genuine interest and by an eagerness at least to try out the new schemes with the children. There are those, however, who strongly oppose the changes having tried them out; there are those who maintain that the schemes will never be implemented because they are far too expensive, and this to my mind is a distinct possibility; there are those, however, who have "jumped on the Nuffield bandwagon" without any examination or analysis of what is being offered and this is most regrettable.

The 11 - 16 projects were tried out in a few modern schools and the comments from the trials teachers seem to indicate that, generally speaking, these projects are not suitable, at least in their present form, for most modern school children. For help in planning science education for the average and below average child we ought perhaps to look first at "Half Our Future", a report of the Central Advisroy Council for Education, the Newsom Report, published in 1963, (+ 17). The report gave the name "anti-science" to the science teaching which merely confirms foregone conclusions, too common in many schools. While it is important, the report says, that good pupils should not be fed this anti-science, it is even more important that the not so clever should not be exposed to naive acceptance of revealed truth. In practice this means a syllabus consisting rather of a small number of relatively extended pieces of work than a large number of excursions. All fields of science should be involved at least in the early years, and so general science is advocated. A plea is made for a partnership between teacher and pupil in the investigation of the immediate surroundings which can act as the source for all the science required. Practical work by the pupils should be the basis of the course since it re-energises the disheartened, provided the pace is slow. While the Nuffield schemes tended to play down the value ofthe children's records of the work done, the Newsom report sees them as important tools in the development of tidiness in learning and confidence in success. There should be a marked change in attitude, it is suggested, in the fourth year, when an element of choice should appear, not the traditional choice of one or more of the formal science subjects but a choice more concerned with interest or vocation or aptitude. A combination of science with a craft such as woodwork, housecraft, or gardening, is suggetsed to bring out the relevance of science to the future occupations or further education of the pupils. The report looked forward to the raising of t he school leaving age when all pupils will stay at school till they are sixteen and maintains that although the oustanding coordinating themes of science may be beyond many pupils of the middle or lower abilities they should all have at least the opportunity of meeting them.

The Nuffield Foundation had promised to produce a scheme of work for the "Newsom" child and in 1965 the Schools Council published as its Working Paper No.1, "Science for the Young School Leaver", (+ 79), for the Nuffield Foundation. There were many references to the Newsom recommendations and the syllabus of the working paper was built round eight main themes in the spirit of Newsom. Each "theme" was broken down into "Fields of Study". The teaching method suggested was that for two years a broad approach of enjoyable investigation should build a structure of science background which could be used in the second phase, thirteen to sixteen, when the relationships are underlined, the threads are drawn together, and the pattern emerges. The project offered flexibility so that pupils of varying ability could work together over the same breadth of field but with different depths of study, but it also offered a structure of related fields within themes which themselves had a recognisable linkage. The Nuffield 11 - 16 project had given full details of practical work, for which much new apparatus was designed and manufactured, and for which there was considerable publicity, but the "Young School Leaver" offered no details of practical work and no list of new apparatus, and very little comment or discussion has appeared about it. The working paper was, however, only a starting point for further curriculum development and trials of the scheme are at present being carried out.

The future of secondary education appears to be in comprehensive schools and we must find out how the work done in science in grammar schools and modern schools is relevant to the comprehensive schools and to discover or estimate what the particular problems are in science teaching which are peculiar to the comprehensive schools. As yet there is no publication from the Department of Education and Science on comprehensive school science, but we must remember that the 1960 Ministry of Education publication, "Science in Secondary Schools", (+ 29), did not relate its recommendations to any particular type of school.

Recently, (1967), the Association for Science Education published "Teaching Science at the Secondary Stage" (+4) and since it claims to be a handbook on the teaching of science to the average pupil and a replacement for the ten year old "Secondary Moderm Science Teaching" (+ 83) there is some discussion, though brief and dispersed, of the needs of the comprehensive schools. We can also find some assistance in developing thinking in this field from sections of individual books on comprehensive schools, such as "Comprehensive Schools", by H.R.Chetwynd, (+ 19), "Comprehensive Schools in Action", by Roger Cole, (+21), the Comprehensive Schools Committee's "Comprehensive Education", (+ 23), the Incorporated Association of Assistant Masters' "Teaching in Comprehensive Schools", (+ 43), and "Values in the Comprehensive School" by T.W.G.Miller (+ 31). However there is no authoritative statement relative to science teaching in these schools so we are left to estimate and prophesy ourselves.

Only the comprehensive school faces the problem of having a complete ability range of children. Can one scheme of science teaching cover the wide spectrum of ability found in each school? The Department of Education and Science and the Science Masters' Association have both said that the same principles apply to all children, yet the Crowther report recognises that while some children, a minority, enjoy an academic approach and benefit by it, for many a different empirical approach is better. There is indeed a third group of children who cannot be expected to follow any form of logical argument, no matter from which direction it is approached. In a recently published,book, "Science in the Introductory Phase", 1967 (+ 5,p.6.), the Association for Science Education says that it has often been found wiser not to attempt a "parallel teaching" syllabus with both above average and less able pupils, but rather to have different schemes to suit different needs.

Mrs. Chetwynd's school, Woodberry Down, had the same science syllabus for all pupils for the first two years, then one year during which physics, chemistry, and biology were each taught for one term, followed by one or two years of separate science subjects selected by the children. This would appear to be an unusual science scheme which would not be advocated for general use, but whichever scheme is adopted ther is the obvious need to see that the best pupils are able to move quickly and deeply into their science, while at the same time the very slow are able to work purposefully at their own rate. If it is possible to provide a single flexible scheme with an obvious structure and purpose this would seem to be desirable since an introduction of two different science schemes in the one school implies some form of selection and this brings with it difficulties of too early specialisation and lack of transfer facilities in the middle and upper school. Not only has the comprehensive school pupils with a wide ability range, but it has pupils with a wide range of ambitions and needs. There will be the desire to offer science courses with many different biases, run in close association with many other subjects, particularly in the technical and craft categories, and this multiplicity may well tax the staff beyond its capacity.

Perhaps the greatest problem facing many teachers who are to be introduced for the first time to children of the lowest ability is to recognise that, at this level, the function of science education may be no more than assisting in the general encouragement of the child to communicate intelligibly.

However we decide to construct our science schemes in comprehensive schools, almost all opinions agree that the basis must be activity and investigation by the children, and a pupil - teacher relationship of cooperation rather than a unilateral demonstration of infallibility must be built up.

Turning now to primary schools we must first appreciate that sixty per cent of non-graduate teachers are in primary schools. The figures given for 1966 in "Statistics of Education" (+ 34,p.18), for qualified teachers in maintained schools are:

| | PRIMARY | MODERN | GRAMMAR | OTHERS | TOTAL |
|---|---|---|---|---|---|
| Non-grad | 135049 | 61623 | 10093 | 23178 | 229943 |
| Grad | 5917 | 11561 | 29203 | 12008 | 58686 |
| Total | 140966 | 73184 | 39296 | 35186 | 288629 |

We must recognise that the majority of College of Education students go to primary schools and to some extent the science that is taught them in those colleges training primary schools teachers must be related to this situation. The patternof recent advances in the teaching of science in primary schools is in many respects clearer than the varied picture in modern schools. Within the last ten years several groups have been working towards very much the same ends and the form of science in primary schools is gradually changing.

In 1960 the general practice was to teach Nature Stduy as the only form of science, with virtually no reference being made to anything outside the biological sciences, and quite often limiting the field to botany. This can be seen to be true by examining a typical book for primary school teachers, such as "Basic Requirements in the Junior School" (+ 65), the second edition of which was published in 1960 by the North-Eastern Junior Schools Association. This small but valuable book of some sixty pages devotes only two pages to "The Study of Man and his Work in the World", which deal with history, geography and nature study. The whole of the reference to science is contained in two sentences:

> "In many city schools it is difficult to give children first-hand contact with living plants and animals. A nature study table or corner can be set aside for treasures the children find; nature calendars, window boxes, school gardens, aquaria, are all possibilities." (+ 65,p.34)

If we look at - standard Nature Study books of this time such as "Nature Study for Schools" by K.S.N.Kirby, (+ 50), "The Teacher's Book of Nature Study" by Fisher and Smyth (+ 37), and "Nature Study in Town Schools for Children Under Eight" by G.E.Allen (+ 1), we see that observation, identification and classification were the characteristic three stages involved, and rarely was any problem solving or conclusion drawing thought to be desirable. It is against this background that we must view the far reaching changes of recent years, during which it is of no mean significance that the School Nature Study Union has renamed itself the School Natural Science Society.

In 1958 the National Froebel Foundation, which had been actively engaged in experimenting with primary school science projects, published a pamphlet, "Scientific Interests in the Primary School" (+2), in whichit suggested that the nature study field is too narrow. The meaning of science in its junior school context is defined and this is given as the whole range of natural forces and all the living and inanimate objects which are available for observation. The N.F.F. then puts its finger on the critical distinction between "nature study" and "science";

> "On the whole, nature study is descriptive. When exploration and enquiry become more detailed, experimental, analytical and systematic, then nature study, or natural history, is developing into pure science." (+ 2,p.2.).

The same basic philosophy that we have seen in the Nuffield suggestions for older children appears here from a different source and in a very different environment.

The application of this philosophy in the primary school produces, of course, very different results, in terms of teaching methods, from those found in secondary schools.

In addition to the National Froebel Foundation, contributors to this movement between 1958 and 1966 were the Association of Teachers in Colleges and Departments of Education (+ 6), the Ministry of Education (+ 30), the New Educational Fellowship (+ 63), the British Association (+ 8), and the Association for Science Education (+ 3), and many private individuals and teams. All the authorities who have come forward with propositions for primary school science have several points on which they all agree. The course should be "unstructured", that is there is no rigid syllabus which must be followed at all costs. The activities must be child initiated, though of course considerable assistance will be given by the teacher, but this assistance is to help the children to clarify the problems which they themselves provide. However Varied the activities of the members of any one group may be there must be a keen sense of group activity, and all forms of communication should be used to bind together the resulys of the separate investigations of the group members. The investigations which the children carry out are concerned not only with a knowledge of the world but with a way of gaining the knowledge. Observation alone is not sufficient; the sifting of evidence and the drawing of valid conclusions are the goals, however demanding these may be.

There are no subject boundaries in primary school science; in fact, this "learning by discovery" may range # far and wide, even beyond the bounds of what, in secondary schools, would even be called science. The Consultative Committee Report, "Children and Their Primary Schools" (Plowden Report) says of the content of junior school science:

> "The conventional ways of categorising these phenomena as biology, branches of physics such as optics, electricity and magnetism, chemistry, engineering and so on, are neither natural nor, except very crudely, understandable classifications to young children of primary school age. If, for the terms used above, rabbits, railway engines, telescopes, T.V. sets, and aeroplanes are substituted, these are at once seen to be things about which children show a spontaneous curiosity and ask endless questions. The subject matter of primary school science thus almost settles

itself. It is those objects and phenomena in the physical world which attract and interest. (+ 18,p.241).

A summary of a case history of one investigation carried out in a primary school in Bell's Close, Northumberland, will give quickly an idea of the nature of a typical class activity. A mixed class of nine to eleven year olds discussed possible visits near the school and it was decided to visit the local brickworks. The route from quarry to mixing plant to machine shed to kiln was traversed by the children and teacher. The questions which the children asked during their visit were remembered afterwards and written down. Back at school four groups were divided off and group folders were begun. Some children contributed writings, some drawings, some models, and at this stage the proceedings were similar to the follow-up stages which classes have carried out since school visits began.

The teacher then carried out further discussions with the groups and gradually problems were formulated by the children which they then considered with a view to solving. In almost all cases it was decided that more survey and observation would be needed before the necessary information could be obtained. Here, however, their appeal was not to books but directly to the sources. They collected bricks of various types to compare their structures, they collected clays from a nearby clay pit, the plants associated with the clays were also collected, seeds were sown in different clays, in soils and sand, bricks were weighed wet and dry, and many other activities begun. Some of the groups whose problems had in the first place been rather vague found more precise definition of what they were trying to find out, some of them changed their problems for new ones. At all stages the whole class was kept informed of what the groups were doing and discussion about improved methods were carried on. The advice of a local College of Education was asked so that an outdoor kiln could be built.

Without going into more details it will be enough to list the seven group problems which were finally investigated:

1. Comparison of the properties of different bricks.
2. The building of an outdoor kiln and the firing of pots.
3. The porosity of bricks and the building of a brick wall with a damp course.
4. The rates of germination of seeds in different soils.

5. The classification of plants of a clay habitat.
6. The efficiency of plant roots; the force required to remove them from the soil.
7. The mechanics of the machines built during the work.

Many teachers, presented with examples similar to that just given, express fear and consternation that they may be expected to carry out work of this type. Many are the forms of expression of this fear: "I never did any science at college", "I wouldn't know how to begin to make a kiln", "I don't know one flower from another", "I was never any good at science". Not only may the teacher feel ignorant of the facts, but he may share with other members of the general public a vague fear of science itself and a belief that, in some odd way, young children should be protected from it. Many people think that study of science will kill imagination, since science is concerned only with "cold facts". There is also the fear of the result of applied scientific technology in the form of atomic bombs and rocket missiles. For many, science represents the bad dreams of science fiction which has almost always a considerable element of fear and alarm. One of the most difficult fears to cope with is the fear that if the young child is asked to find out for himself by direct recourse to the original situation rather than by asking the teacher we are in danger of rearing a generation of sceptics who will question all adult authority. There are also the particular fears concerning science in the school, that classes are too big, that not enough apparatus is available, that teachers simply have not the energy to carry out strenuous programmes of this nature, that there is an element of physical danger for the children in scientific investigation. Only by a better understanding of science itself can the fears of teachers be overcome. Teachers in primary schools who are being asked to "try out some science" are not generally those who have had any specialised training in science and they cannot be expected to relish the idea unless they have been prepared for it in some way beforehand.

However there has been published recently (1967) by the Nuffield Junior Science Project a set of books consisting of teachers' guides, source books, and background booklets (+ 69) which should be of considerable help to primary school teachers and College of Education students who wish to involve themselves in this exciting and promising field of science teaching.

It is possible that these Nuffield books have little completely new to say, but a wealth of experience from trials teachers and team leaders has been collected together and spelt out in great detail and with convincing persuasiveness, and it is certain that many teachers will becomes advocates of this new way of learning. The Schools Council has added its weight to the proposals offered by the Nuffield and other projects by presenting an analysis of the present situation in its Field Report No.5, "Science in the Primary School", (+ 81).

It has been recognised by the Association for Science Education that curriculum development is necessary in the area which lies between what has become known as Primary School Science and the more formal schemes in separate science subjects proposed by the Nuffield 11-16 Science Project for secondary schools. In a book published in 1967, "Science in the Introductory Phase" (+ 5), the Association produced an example of an integrated science scheme for the first two years of the secondary school in which the discovery methods of the primary school are continued and developed. The emphasis has moved, at this stage to laboratory work, but it is still based on the interests and common experiences of the children. As the course proceeds it introduces more formal learning and encourages the acquisition of skills which will be useful in later science courses. It is appreciated that many secondary school science teachers are highly qualified specialist who may feel that they are not suited to the teaching of an integrated course, but the Association is confident that whatever obstacles there are can be overcome provided the teachers have active and enquiring minds.

Of the Nuffield Science Project teams at present, (1969), carrying out trials, two, the "11-13 Combined Science" team and the "5-13 Science" team, are concerned with programmes which will help teachers of children in the middle years, and results of the trials are soon to be published.

We see then that the roles of the science teacher in both the secondary scholls and in the primary school have changed considerably in recent years and are still changing. There will have to be changes in the kind of science teacher prepared for the various types of schools, in the relationships between teacher and pupils, and in the relationships between the science teacher and the other members of staff.

Very often the grammar school science teacher has been an honours graduate teaching only one science subject, unable or unwilling to widen his range of teaching into sciences other than his own, finding his principal satisfaction in his sixth form pupils whom he prepares for university entrance or scholarship. It has been only too common to find little cooperation between the teachers of the different science subjects in the same school, and some areas of study on the borders of subjects have been duplicated while others have been omitted. Active cooperation in science between pure science subjects and applied science subjects such as engineering, horticulture, and housecraft, has been rare in grammar schools and even more rare has been combined activity with other subjects like geography and mathematics. Without doubt there will have to be much greater cooperation in future and all teachers will need to engage in more flexible programmes of teaching.

Instead of focussing attention on the restricted areas of individual sciences, the school science programme will have to display to the pupils a much broader canvas so that the all embracing principles of science can be outlined. The gaps between science subjects, often wide in the past, will have to be closed up, and all members of the science staff will have to take part in helping in the integration. Perhaps the most important, and possibly the most difficult integration will be that of the biological and the physical sciences, so that all pupils may continue to study both of these areas throughout the main part of their school lives, and only in the sixth form or its equivalent will specialisation begin. It is interesting to note that the Schools Council has recently (1969) begun a Project in Integrated Science to "o" level.

In his own sphere each teacher will need to question the advisability of using the examination syllabus as his teaching syllabus. Of course it would be unrealistic to suggest that public examinations should be ignored, but many teachers have covered all the ground of a particular examination syllabus, no more no less, fitting it in exactly in the time available. This is too rigid an approach and some time must be allowed for variety of interest and pace and depth. Inevitably this will mean the neglecting of some parts of the syllabus and substituting fresh and perhaps unproven activities. Room must be left for purposeful digression since this is the very essence of scientific investigation.

It is most uncommon to find the science teacher working in any place other than the laboratory or the classroom, not only in grammar schools but also in a large number of modern schools. The many situations outside the laboratory which could be used for scientific interest and investigation are largely ignored. What little field work is done usually consists of routine soil sampling and unimaginative and tedious line transects and quadrat counting, while greenhouses and school gardens are often used only to grow flowers and vegetables. Many science teachers never consider working outside even though there is tremendous scope out of doors, even in an unpromising looking city. If the science teacher broadens his outlook and includes as sources of interest and inspiration the children's homes, the local industries, the spare time pursuits of the children and their probable future jobs, he will undoubtedly teach better science.

The role of the teacher in the child's learning situation is changing and we must hope that this change will continue somewhat further. The authoritative method of science teaching whereby the teacher alone plans what will be studied, learned, and tested, and in which the practical work is predetermined, is not only lacking in interest and excitement but is poor science, with pupils learning from the teacher or from books only in order that sequences of questions, related to an examination, may be answered. Teachers must find ways to allow the pupils to inaugurate investigations and to contribute original thinking. There must be more discussion between the teacher and the class about the purpose and the structure of what is being done, about which methods should be tried out, about how these methods could be improved, and about the meaning of results obtained. Some teachers are still unwilling to admit that there are questions within their subject which they cannot answer. One of the changes in attitude needed for some teachers will be a movement away from a position above and in front of the class to one in amongst the children.

It is still common to find that all children in the same class are expected to travel at the same rate to the same depth in the same time in their science. In future much more attention will have to be paid to individual needs, with the teacher trying to keep the brighter children on the move, and encouraging and helping the weakest at a slower pace. This will result in different end points but this is inevitable and the teacher must estimate what is reasonable in each case and be satisfied with this.

The primary school teacher is quite used to coping with children moving at different rates and needing different amounts of assistance, but the change in attitude to science which she will be asked to consider is that of extending her young pupils' work from observing and collecting to questioning and investigating. The role of the teacher in the primary school science situation will be to provide the interesting and stimulating environment, the materials, and the advice, to maintain the children's enquiries. The provision of materials for this kind of enquiry work is a formidable task and all resources must be used, particularly that of the children's homes, where most of the simple bits and pieces suited to this work can be found.

The primary school teacher will appreciate that investigation methods can only be carried out by children who have been trained over a period of time to use their own initiative and that this training can be carried out only if the climate throughout the whole school is sympathetic to it. The teacher will need a cooperative and accommodating headmistress who will give her the opportunity to gain the understanding and help of the other members of staff.

Primary school teachers are under considerable pressure from many directions to introduce new teaching methods not only in traditional fields of reading, writing and number, but in expanding areas of mathematics, French, geography and other subjects. It would not be possible, even for the most willing and conscientious, to keep up to date in all these modern movements and it would seem highly desirable to have in each primary school at least one member of the staff who could be considered to be a science specialist. Not that she would be expected to teach science as a specialist subject throughout the school but that she should make available materials appropriate to the children's needs, advise the staff on primary school science teaching and keep them informed about new ideas and opinions. It will take many years for the recent suggestions about science teaching to filter in to all the primary schools and some kind of science specialist could help to accelerate the process.

It has been the fate of many children at the age of eleven to have been moved abruptly from a primary school based on class teachers to a secondary school based on subject teachers, from a school where if science was taken at all it was very simple and informal to a school which plunged into physics, chemistry, and biology, in a very formal way. It is hoped that in future the highly formal methods of teaching science at the secondary level will be modified, but nevertheless, if abrupt changes are to be avoided, a "bridge" form of science teaching has to be devised to carry pupils from a free and unstructured method to a more organised form suitable to lead into public examinations.

In some parts of the country children between nine and thirteen will attend Middle Schools and as it is in this age range that the "bridge" science teaching will take place it might be called Middle School Science. What will be the role of the science teacher in the Middle School? It is hoped that our science programmes will encourage children of all ages to participate actively and to think as deeply as they can about what they are doing. In the early years we depend largely on the child's natural curiosity and exuberance to provide the impetus for investigation, but as the children pass through the Middle School years some of them will lose much of their curiosity and exuberance and more positive steps will have to be taken to retain interest in the study of science. This loss of curiosity for some children will occur early, for some late, and for many naive curiosity will disappear and reappear many times over the years. The science teacher in this age range will need to use both simple and sophisticated incentives. The bright pupils will need intellectual satisfaction and evidence of logical progression as the work becomes more formal, while the weaker children will need to be satisfied that what they are attempting is within their capabilities and is worth trying. Teachers will need to study how these inevitable divergencies can be reconciled within a single school community. If it is thought that in a school with full ability range different science teaching methods are needed, some logical and deductive, others empirical and practical, problems of criteria for selection will arise. The teacher here would have to be, among other things, a selector.

About this time also the need arises for the information gained and the techniques acquired to be organised into a coherent, balanced pattern. In order that the children, on leaving the Middle Schools, are best prepared for the science they are to receive in the High Schools, or their equivalents, it is clear that all science teachers should kbow how science is being taught in the schools with age ranges above and below their own, and should keep in touch with the changing trends of science teaching. We must see that the students we are now training will themselves be eager and able to initiate and implement the changes that science teaching will always need to keep it lively and purposeful.

CHAPTER FOUR

## PRINCIPLES OF CURRICULUM DEVELOPMENT IN SCIENCE

Most discussions on curriculum development in science begin with some form of definition of aims or objectives. Several authorities have said that this is essential before curriculum consideration can begin, among them the Association for Science Education (+4,p.120) the Organiser of the Nuffield Physics Project, (+ 78,p.4), and the Vice-Chancellor of Durham University, (+ 20,p.7). Some commentators, however, have said that lengthy discussion of aims is not profitable; one of these, for instance, is J.S.Bruner, the spokesman for those who made up the Woods Hole conference in 1959, to which I shall refer later in this chapter. He advocates a statement of only modest goals, suggesting that in the process of trying to reach these goals we may learn much about what our true aims are.

I agree with the need for some definition of aims or objectives and I shall try to evaluate some of those aims which are most commonly advanced, but first it is important that we should appreciate a point made by several authors - that the aims of science teaching are very different for different age groups of pupils or students. While some general objectives apply to most age groups, the particular age group involved in any given course must be specifically considered before enumerating aims. This appears to be reasonable and I would go further and say that if our older pupils or adult students know what their future careers are to be, then inevitably our aims can be more precisely defined.

In recent years the need for science education in general for all groups of the community has been widely discussed, a typical occasion being the lecture by C.P.Snow on the "Two Cultures" (+ 91), when he claimed that our society had become sharply divided into the scientists and the non- scientists and that communication between the two groups was rapidly dwindling and soon, unless steps were taken quickly to remedy the situation, there might be a chasm of misunderstanding separating the two cultures.

While it is often said that scientists must make positive efforts to talk to laymen in simple language, it should also be said that the laymen must meet the scientists half way. Only if the layman learns more than he knows, on average, now of the language, methods, and motives of scientists will it be possible for even simple communication to take place. Moreover, the layman cannot opt out of the obligation to take part in scientific discussions. If new technologies are not understood, at least at the simplest levels, almost certainly unjustified fears will build up, will be magnified and distorted, and will breed suspicion and distrust of science and the scientist. The fears of the neighbours of Frankenstein and the mistaken ideas of the dangers of snakes are repeated over and over again from country to country, from generation to generation, so that fact and fiction, science and magic, become confused and interwoven. Apart from the need to conquer fear we must have a scientifically educated public to prevent the technical expert, the specialist scientist, from being left to make decisions which should rightly be made by the whole community. We must know, all of us, enough to join in the advances of our civilisation which appear to be inextricably involved with the penetration into what have previously been called the secrets of nature. Professor Eric Rogers has placed the necessary stages of the layman's knowledge at three levels; he says we must know what science is like, what scientific work is like, and what scientists are like (+ 78,p.9). The first is the most difficult to teach he says, but if we succeed only in the third we may well be satisfied.

Apart from the general or civic need for improved science education, most objectives fall into one of three categories, cultural, vocational and disciplinary.

There is very little resistance nowadays to the claim that science must take its place beside the other subjects which go to make up the content of a cultured man's awareness, so that some commentators have tried to be more specific. Dr. Christopherson, Vice-Chancellor of Durham University, for instance, (+ 20), says that we need to teach people how to be at home in a modern age and to show them that scientific method is a normal approach to any intellectual situation, and the primary solution, he suggests, is to teach the layman the language of cience in a simple way. Thes opinions have obvious truth in them but I think many people would require greater precision in interpretation of terms, for instance of "scientific method".

Part of "being at home in a modern age" will involve the big problem of preparing for a wise use of leisure in a technological era and the educator in science must consider it as part of his duties to equip his students not only for professional life but for leisure time.

Lord James, former High Master of Manchester Grammar School, thinks that a difficult but essential task of the science teacher is to make clear the social results of scientific advance and its relationship to the development of human thought (+ 44). Unless the teacher consciously plans for this, he says, he will fall into mere factual teaching.

That science deals with facts only, that it stifles imagination, and that it is unemotional are commonly held beliefs and one of the cultural aims in teaching science should be to show that within science there is endless scope for imaginative invention, for emotionally satisfying enthusiasms and or just as much creative expression as in any other field of intellectual activity. Those who would draw a sharp distinction between intellectual and emotional training do a disservice to science if they create the impression that it holds no power to conjure up deeply felt enthusiasms.

The second group of objectives in science teaching can be broadly classed as vocational, but there are many shades of interpretation of the word and some explanation of its use is essential. There has always been condemnation from many sides of teaching science from a strictly utilitarian standpoint, and a dislike of courses entitled, for example, "Building Science","Applied Heat," and "Welding Science", when these course deal with a very specialised field and consider only that which would be of immediate concern to the craftsman or tradesman under training. For instance, the Norwood Report disliked the practice of rural schools teaching a form of Rural Science which was narrowly vocational (+ 88,p.108), and much of the science taught in Technical Colleges drew this comment from the Crowther Report.

> "Some of it is perilously close to the line that separates education from mere instruction."
> (+ 16,p.369).

There has been considerable agreement that the best preparation for anyone who needs to apply scientific knowledge, even in a very restricted or specialised field, is a good grounding in basic principles. It is often difficult, however, to convince the student, whether he be a sixth form pupil taking physics in order to enter a medical college, or a day release apprentice studying Engineering Science, that a broad field of study in science is best for him.

On the other hand there is a growing awareness that the vocational incentive to learning may not have been as well exploited in the past as it might have been. Both the Crowther Report (+ 16, p.178), and the Robbins Report, (+ 22, p.6) have emphasised the value of linking education with ambition and with the day's work. Many students in the establishments of further education would never have gone there if they had not believed that they would be influencing their careers significantly. The motive of self-advancement is not discreditable and it is not uncommon to find that quite surprising interest is aroused in some students who were very reluctant originally to commit themselves to a course in science. In particular we must consider the use we make of the vocational incentive in the training of teachers in science, especially of those who may feel that without science training there will be reduced confidence in the classroom.

The Association for Science Education (+ 4, p.7) takes a broader view of the vocational emphasis when it suggests that the aim of all institutions of education, at whatever age level, is to enable a person to accommodate himself to his environment while developing his own personality. A critic might suggest that the main of education should be more forward looking and should suggest an ambition or desire to move onward from the present environment, and that "developing a personality" only begs the question of what guidance should be given and in which directions when personality development is concerned. I think that it would be much easier for a young person to extend his personality and to open up the talents of self expression which may be latent if he knows where these characteristics are to function, and again in a college which trains teachers we have the advantage that our students know the field in which their talents are to thrive.

It is within the third group of aims, under academic disciplines, that the major discussions have occurred, and this is largely because of differences of opinion about the quantity and quality of what is usually called " transfer of training". The problem can, in its simplest form, be reduced to a decision as to whether one believes that the "mind" can be trained. Somewhere or other in almost all statements of the aims of science teaching one can see the assumption that there is some transfer of training, often without direct reference to the subject. Phrases like, "the general powers of the mind", (Robbins), "considered as a mental discipline", (Science Masters' Association), "training a pupil in consistent thought", (Ministry of Education), are common enough for a generalisation to be made that there is widespread belief in the value of teaching science because of its effect as a mental discipline. Some authorities have argued that even if there were considerable doubts about transfer of training, science teaching is not subject to these doubts as it deals with the very field of physical things in which men and women carry out the major part of their thinking. Others say that the area which science covers is so large a part of man's everyday life that training in its methods needs no further justification.

Following at least partial agreement that science education has a contribution to make towards faculty training some specific approaches which are suggested are that students should learn how to approach a problem scientifically, how to plan scientific investigations, how to formulate scientific problems, and how to design experiments which are scientifically valid. All these aims may well be laudable but they suffer from an incomplete definition of what is meant by "scientifically".

perhaps we can accept Professor Eric Rogers summary of the three conditions under which we can accept that sufficient transfer of training takes place to justify our claim for science education as a mental discipline. There must, he says, be sufficient common ground between the primary and the secondary fields, there must be conscious effort on the part of both teacher and student to teach and learn towards specific transfer, and there must be a strong element of enjoyment, interest, or incentive.

It is the theme of interest, coupled with that of understanding, which is a common feature of much emphasis in curriculum discussion. Incentives can be long term or short term. Long term practical incentives, such as natural ambition, passing examinations, gaining qualifications for a good job, the achievement of status, are generally recognised as being a powerful factors for only a small minority of the population; for most of us these goals are too distant. And no one nowadays includes fear of punishment as a legitimate incentive. Short term incentives such as pleasing the teacher or a parent, novelty, satisfying curiosity, and dramatic appeal, are generally more obviously valuable with younger children but even then their effects may only be short lived and no teaching programme can hope to depend on these for more than part of the time.

A few people have a natural satisfaction in intellectual exercise for its own sake but they are so few that we need only envy them and pass on to consider the others. What we really want to know about and use is the key to the secret of why many people can become completely absorbed in any one of a variety of activities and pursuits. When we consider how many hours people spend in the most astonishing hobbies we realise that many of us in schools and colleges have never even begun to tap this immense source of energy of concentration. What is it which drives a radio "ham" to spend years of his life building sets and sitting through the nights listening for his distant pips? Why do some men spend hour after hour sitting alone on the top of a cliff watching sea birds? What is it that enables the club tennis player of limited abitlity to look forward with eager anticipation to hitting a ball backwards and forwards over a net, just as he has done fro ten, twenty or even forty years? Professor Inhelder of the Geneva School (+ 11) has called for much more research into finding out why people become completely absorbed. At present there seems to be no reasonable explanation which would help us to take advantage of it in a systematic way. More easily understandable are those absorptions which depend upon the pride in an acquired skill, whether it be muscular as in the case of an athlete, or constructive as inthe case of the potter. These incentives we must use in our teaching.

The satisfaction of having found out something has been mentioned before and no doubt we shall present students with plenty of opportunities to satify curiosities but we must be well aware that some of them will tire of curiosity as their sole incentive. Imagination has to be encouraged, and joined with understanding, it will produce skills which will last much longer than tediously learned information which, as Professor Nowell-Smith points out (+ 66,p.17) is easily forgotten when it is not used regularly, whereas skills are rarely forgotten even if they are not practised for long periods.

It would be foolish of us were we not to take advantage of the results of the enormous amount of research work which has been done in the United States in the last eight or ten years on science teaching curricula. Perhaps one of the most searching investigations into science teaching took place in 1959 at Woods Hole on Cape Cod, where there were gathered together thirty four of America's most distinguished scientists and educationalists. The director of the meeting was Professor J.S.Bruner, and he has given an account of it in "The Process of Education" (+ 11). In addition to dealing with topics which I have already mentioned, the conference stressed two particular themes which are of interest to us, one about structure and the other about intuitive thinking.

The conference came to the conclusion that not enough emphasis is usually placed on the relationships which should exist between the several skills, experiences and conclusions which go to make up a science course - this system of relationships they call the structure of the course. They say that both the teachers and the students should be absolutely clear as to the function of each part within the whole for three reasons. One is that not everything in any course can be exhilarating and exciting but if the duller parts are seen to be essential for the complete pattern then they will be studied if not with enthusiasm at least with purpose. The second reason is the conclusion that experience shows that principles and laws are easily forgotten unless their places in a logical pattern are seen easily and clearly. And thirdly, if we are to lead students from particular experiences to valid generalisations we must give a basic structure into which the student may fit his parts in order that he may see the emerging picture.

The importance given by the conference to this conscious teaching of interdependence or structure is more than other authorities usually give, but one must respect the judgement of this highly qualified and highly experienced group of teachers. If we remember the enormous advances that were made in inorganic chemistry following the acceptance of the Periodic Table perhaps we could take this as a specific example of the kind of structural relationship which the Woods Hole conference was so keen that we should try to find in all our science teaching.

The conference also discussed the role of intuitive thinking in scientific method. One conclusion arrived at was that very little was really known about it with any certainty, but at the same time consideration must be given to it by those devising any science course. In connection with the course we are considering for our prospective teachers, there are a few simple conclusions which have emerged from discussions such as those at Woods Hole, in Brazil, and in Europe, about intuitive thinking which will interest. One is that while it is of immense importance in research work to use intuitive thinking alongside logical analysis, probably only the gifted few can use their intuition profitably and even these few can only use it when it is based on a sound and comprehensive foundation of rigorously tested information. What we can do in this direction is to allow our students plenty of opportunity to guess, when their guesses can be checked by measurement, so that they may learn to evaluate in some circumstances the cost of guessing and in others, the cost of not guessing. This may not be intuitive thinking by any definition, nor may the use of heuristic techniques such as probability, analogy, simplicity, and the rest, but the value to the student of non-rigorous argument is high, and I feel, not appreciated as well as it might be.

One final point from the Woods Hole conference. Just as no course should be designed so that only the gifted can pursue excellence, so no course should be designed for the average student. Ideally our course must challenge both the superior and the inferior student to reach his personal best.

The organisers of the Nuffield Science Teaching Projects in this country have all acknowledged their debt to the three American science curriculum development schemes, known in abbreviation as PSSC, CHEM Study, and BSCS. From the mass of detail given about the development of these curricula, I should like to take only two points. The physics course devised by PSSC was built around two central notions, wave-particle duality and the modern concept of the atom, and only those portions of physics which contributed to this twin column structure were included. That there were enormous omissions of what many people would call fundamental physics was not considered to be any disadvantage. The CHEM Study group based its course on only two principles, that there should be an excellent set of laboratory experiments and that the course should emphasise the importance and limitations of concepts which led to an understanding of the relationships of the parts of the subjects.

It will be of advantage, at this stage, to summarise the objectives which I feel will help to determine the curricula for our students in Colleges of

Education. Different ages and different groups of children and students will have different purposes in studying science but some general aims apply.

Our students should be informed about science, cultured in science would perhaps be a better phrase. Not that they should acquire a large store of factual information, mathematical, physical, and biological, but they should build up a balanced picture of the important general principles of science which govern man's place among his fellows, his place in the world, and his place in the universe. They should be able to discuss, in general terms, the questions about mankund which are raised because of scientific or technological advances, questions such as "What are the biological effects of radioactivity?", "How can the world food supply be increased?", "Can the weather be changed?", "How can we prevent pollution?".

One important aim of our science teaching should be to educate our students to the point where prejuduce and bias in judgement has been eliminated. The approach to science and the way in which it is studied should be such that reasoned and objective discussion is seen to be the only sensible way to the solution of problems.

Even though scrupulous honesty is demanded in our scientific argument this will not be transferred to evryday problems, charged with emotional and cultural pressures, unless we specifically teach towards such transfer.

While advocating a logical and objective attitude to evidence and conclusion in science, we must emphasise that science offers scope for emotional and artistic experiences as much as any other branch of learning. Apart from obvious areas like colour and sound, we must show our students that shape and pattern in crystal e structure and growth, the mesmerising effect of Brownian motion, the building up of a sand pendulum picture, the complicated behaviour of a hive of bees, all subscribe to a study of science in which beauty and wonder, surprise and excitement, combine to provide enormous satisfaction. In addition to this intellectual objective we must give students the opportunity to feel the craftsman's pleasure in having designed and made something, no matter how simple, which does well the job it was meant to do.

We should aim to show our students what is meant by "scientific method" - the phrase is often used and no dounbt will be used for a long time yet. To say, as is often said, that the "scientific method" consists of five stages, observation and experimentation, analysis of information, hypothesis, testing of hypothesis, substantiation modification or rejection of hypothesis, may be a useful outline of a generalisation, but considerable amplification and explanation will be needed before we can show the average College of Education student what working in a scientific way really involves.

To show the value of thinking and working as a scientist does, and this must be one of our aims, we must take each step in the process and explain it by doing it ourselves and by giving the students the opportunity to do the same. The skill involved and the attitude required for purposeful and successful observation, for instance, will have to be carefully and directly encouraged before students can appreciate that we mean more than just looking. The cultivating and sharpening of all the senses and the directing of attention to concentrated examination will be one stage of our work.

It is often true that a school science course does not give a pupil the opportunity to formulate his own questions. Usually single isolated problems are all the pupil has presented to him and often he is given the answers too. Unless we allow the student to extract some problems, from time to time, from the complex environment in which they are found, letting him dispose of all the camouflage, and then insisting that he sees and states clearly the question he has to set himself, then we have given a false picture of the ways of science. Similarly, in the experimentation stage it is often either assumed that the student will be able, without difficulty, to set up an experiment to provide information or data useful for the problem in hand, or the whole experiment is described in detail and no more initiative is required than for a cookery book recipe. The student must be given enough freedom to see that the setting up of an experiment demands much clear thinking about the selecting of the right apparatus, the setting up of controls, and the processing of the data obtained.

Many students find it by no means easy to decide what valid conclusions can be drawn from the work they have done and if all they are asked to do is to verify a proposition or calculate a physical constant, again the wrong picture of science will be conveyed.

These steps in scientific working are not easy and we must help, but we must also allow the difficulties to be seen and appreciated. We must also let the student see that at several points along the way there is scope for intuitive thinking. There will be, from time to time, choices of apparently equal value, and the best choice will follow well based intuition; but this is all part of the way of science.

When we have given our students a clearer picture of the way in which science works a further objective will be to help him decide the value, if any, of transferring scientific approaches to the situations of ordinary life. An obvious application is to the impact on ourselves of advertising. How far can we bring to bear objective appraisals into this field? Students should be invited to judge how far scientific attitudes should be brought into other aspects of daily life. Are they equally applicable to deciding whether to have double glazing in the house and to choosing a wife?

Because our students are going to be teachers we shall have other particular objectives. Most students come straight from school and go straight back to school, where they teach children, many of whom will later spend a large part of their lives in jobs dominated by technological, industrial, and scientific forces. We may be able to do little in our science courses to show our students how applied science, technology, and industry operate, but we should try, as far as we can, to prevent our study from being too academic, by including some glimpses, at least, of man's application of science to soap or steel or pig breeding.

Those who are to teach science will need information, and part of our course, perhaps a major part, will deal with investigations within the standard range of science subjects. The age range of the children for which the intending teacher is training will be a factor in deciding how much information is needed, but inall cases it will be necessary for the student to have studied to a level a good deal higher than that to which he intends to teach. Our students will need skills and expertise, how to use apparatus and equipment in the best ways, how to anticipate the difficulties which children will experience, and how to organise their resources. They will have to see clearly the structure or pattern of what they are to teach and how to break down the whole into convenient units.

Above all, those who are to teach science must have particular qualities. Within the framework of our course we must cultivate in our students enquiring habits, initiative, ingenuity, original thinking, ability to improvise, and above all, enthusiasm. We can do this if we can make the students realise that within science teaching there is as much scope for research and original work as there is in any research unit. The field is different, the purpose is different, but the satisfaction is the same. The research will be concerned with new methods of presentation, new stimuli for the children, development of experiments, design of apparatus, exploitation of new materials, and if we do not communicate to our students enthusiasm for teaching science as an exciting initiation into wonders and delights we shall have failed.

CHAPTER FIVE

THE CONTENT OF THE MAIN COURSE

The sheer volume of factual knowledge which has been accumulated within the range of science studies makes dome form of selection inevitable at any level of education. Even when courses are restricted to one science subject or part of a subject it is no longer possible to say that all the ground within the chosen study has been covered. Christopherson has pointed out that the idea of "comprehensiveness" in degree courses has disappeared:

> "This idea involves the concept of the standard graduate who knows all about a certain subject up to a certain level. This concept is dying on its feet." (+ 20,p9.)

Lord James has emphasised the need for continued intercommunication between different branches of knowledge as the boundaries of subjests expand and interests become more and more specialised. He sees the need for schemes of integration:

> "We are saved from being overwhelmed with vast accumulation of fact only by the emergence of new principles of synthesis. And these can be

forthcoming only when it is possible to find common methods of approach in quite different subjects. (+ 44,p.66).

Unless there is rigorous selection in any field of scientific study there is a great danger that the quality of the study possible will be diluted and the intellectual satisfaction obtained from it will be so reduced as to render the exercise unprofitable.

The commonest form of selection is that which chooses to study only one of the normally recognised sciences, but the boundaries between the separate sciences are often so blurred and indistinct that traditional classifications may no longer be the most suitable categories which should be offered as bases of selection. Many universities and other educational institutions are offering courses, such as the one in Environmental Studies at Lancaster University, where the unifying theme is not contained within one of the traditional subject disciplines. The Association for Science Education is one of the several organisations which has repeated the need for a breaking down or at least a modification of rigid subject barriers:

"Science is one and undivided in its principles and in its method. The various aspects of science presented to the pupil must eventually be integrated into one coherent whole." (+ 4,p.7).

However since some form of selection must be made, we must consider the arguments advanced for various criteria for selection. Discussion of this nature usually begins with arguments for and against what are often called "breadth" and "depth". Without trying to give too precise definitions of these two words we can consider what some recent commentators have had to say in this context.

The Crowther report (+ 16) presented a case for depth. Able young people, it argued, are eager to get down to serious investigation of some limited topic in the vast field of human knowledge and it would be wasteful not to use this enthusiasm. As a person goes deeper and deeper into an enquiry he acquires greater confidence in his power of mastery of the subject. Only through specialisation and the study in depth which it permits can a person be introduced into regions which illustrate the nature of the world, and in the end such study will bring the student through the barriers of subjects to the far side, which leads to breadth. This represents a fair statement of a principle which has formed the basis of much of our education for those who continue beyond the statutory leaving age. In general however it is not the usual practice to advocate this type of selective work in specialised areas for children below about sixteen years of age. The Ministry of Education points out that the opportunity which our educational system gives to all pupils in the higher levels of schools for specialisation and study in depth distinguishes it from many other systems and is a feature of which we are rightly proud:

> "Most English educationalists hold that an essential part at school level of a truly liberal education in any field is some intensive study of a high standard and that without some thing of the kind, a full education is impossible. (+ 29,p.27).

The Robbins report (+ 22), too, endorses the need for study in depth for certain people, those for whom it is essential to get to the heart of the subject and to develop powers of rigorous analysis. For these people the first degree course at universities in England and Wales is considered to be appropriate. It is significant, however, that this report does specify the type of person who could benefit from this depth study and the implication follows that there are others, perhaps many, who while being suited to further education may not derive enormous benefit from depth investigations. Lord James says:

> "But the most important point that is too often overlooked is the educational value of a fairly deep study of a limited field, even in the upper forms of schools. There is no substitute for this in a patchwork of superficial studies without, and revealing no possibility for, genuine standards of scholarship." (+ 44,p71).

One wonders at the significance of the choice of the phrases in the above extract, "fairly deep", and "even in the upper forms"; could Lord James be thinking only of the education of the bright person when he wrote this and would he also advocate deep study for pupils of average intelligence?

I think that for a number of years there has been a tendency in both grammar schools and modern schools to apply methods of learning which involve study in depth to children who are too young for it and to children who are not intellectually capable of it. Certainly all older pupils or adult students should be given the opportunity to study in depth but I feel that there may have to be considerable modifications in methods of study according to the ability of the students. What is the meaning of "depth" as far as the courses we are preparing are concerned? Perhaps the commonest interpretation of the word in this context is that which results in students acquiring more and more detailed information about the subject or section of the subject which they have chosen. As the total amount of scientific information increases the previous divisions of, for example, physics are further subdivided and in an attempt to attain the maximum depth of which the student is thought to be capable intellectually, certain subsections are dropped from study at various levels of depth, the number of subsections omitted and the levels at which they are omitted being determined by the time available. It is worth repeating that this selection is almost always thought of as being a selection of quantity of information. This very common approach implies that there are two requirements; one, that all areas within the originally selected subject will have been "covered", even though some of them will have been covered only lightly; and two, that certain areas will have been studied as deeply, in terms of information, as the student is capable of studying.

A second, less common, approach is to offer the student a course of options at an early stage so that some areas of the subject are omitted from the course by each student. This method, while satisfying the need to take the student to the limit of his capacity in some areas, does not claim to have covered the whole of the ground in a given subject. Again, however, it is often the quantity of information involved which determines the time devoted to the options. This type of course has the advantage that it can cater for the different backgrounds and different interests of both students and staff, but it suffers from the disadvantage that the set of options selected by any one student lacks any related structure and in time the student may have difficulty in constructing meaningful relationships between the various parts of his course. There is no focus to which he can relate the paths of his different pursuits. If we believe that the acquiring of information is not as important as intellectual scientific discussion then the need to cover the whole ground in any given subject does not appear to be very important. Of course it is agreed that there must be some information available before there can be discussion and the study of the way in which a great man thinks or has thought may well involve a fair understanding of what he has done. It does not, however, require us to know of all that he has done.

In our consideration of the interpretations of the meaning of depth study we can easily distinguish at least two different attitudes, one which considers depth in terms of difficulty and the other in terms of detail. It is profitable to consider whether a young boy of, say, ten years of age is capable of study in depth in a scientific field. If such a boy were to make careful observations, over an extended period of time, into the behaviour of his pet animal, to write down what he had seen, and to find a pattern in behaviour, surely this is good science. The fact that he may have encountered nothing of difficulty or that his conclusions are so simple that he has not offered any original contribution do not affect the issue. It is is one of my premises that good scientific investigations can be carried out by practically everyone at all levels of intelligence and age and that the criterion of originality is concerned only with the newness of the particular problem to the particular student or pupil involved, and the criterion of difficulty is unnecessary. If we accept that study in depth can mean study in detail rather than study in difficulty, it is then possible to argue, as I propose to do, that depth study can begin in an area where there is little or nor previous knowledge, that in fact depth study can be a means of acquiring the necessary information to proceed to more detail and to the drawing of conclusions. This view is in opposition to that which holds that only when basic scientific laws are understood can they then be used to lead to useful study in depth. It is often argued that increase in breadth study leads inevitably to reduction in depth study and therefore to superficiality. This would be true if attempts were being made to cover all the ground over the increasing breadth of study, but if selection is made, then a satisfactory depth of study, as I have interpreted it, can be achieved in the selected areas.

There is support for the plea for increased breadth from many quarters. In the Schools Council publication "Science in the Sixth Form" (+ 53), Mr.J.V.Long, of Her Majesty's Inspectorate, says we are "driven to accepting a survey of the whole field, together with a more thorough exploration of a few patches". (+ 53,p.32). In the same publication J.E.Spice proposes that sixth form study of physics and chemistry should be combined since the simplification which is taking place in all areas of science is of great importance. An enquiry into the suitability of A level syllabuses of the G.C.E. in science as a preparation for direct entry into first degree courses in faculties of science conducted in the University of Birmingham concluded, among other things, that demands for excessive factual knowledge and formal structure of syllabuses was a deterrent to the laudable object of broadening and deepening outlook on scientific matters. It suggested that science courses should be more broadly based, (+ 12,p.F.13). Both the Norwood report (+ 88,p.109), and the Robbins report (+ 22,p.92), regretted the over specialisation and narrowness of many courses. P.H.Nowell-Smith, in an inaugural lecture at Leicester University, "Education in a University", supported the claims of broader courses and observed that "physicists, chemists and biologists are not men who know, but men who are capable of enquiry" (+ 66,p.5.) The Nuffield Science Teaching Project, having produced for its 11-16 year old courses separate schemes for physics, chemistry, and biology, is now involved in the preparation of a Combined Science scheme for 11-13 year olds, and also a combined Physical sciences course at Advanced level for sixth forms.

As we are concerned with science courses for intending teachers it is of particular importance that we consider breadth of science courses in teacher training. Whatever may be said in favour of maintaining traditional narrow courses for non-teaching scientists there would seem to be little to commend them as ideal training for those who will teach. The Ministry of Education in "Science in the secondary schools", is quite firm in its opinion:

> "The training offered by most university honours degree courses is a narrow one and does not, of itself develop that breadth of interest which is essential to the early work in schools."
> (+ 29,p.50).

It also encourages those training colleges science courses where the subject is studied to a valuable depth in a broad front. The Norwood report advocated very strongly the teaching of General Science in schools and, realising that the teaching of it was a difficult task, urged that many more university courses comprising several subjects of Natural Science should be offered to intending teachers, (+ 45,p.109). If broad science courses are being advocated for universities how much more desirable or perhaps essential they would appear to be for Colleges of Education training teachers of younger, and perhaps, less talented older children. The Ministry of Education pointed out that in junior forms of all types of secondary schools the teachers, who will generally be trained in Colleges of Education, should be equipped to teach both physical sciences and biological sciences, (+ 29).

It has been shown earlier in this thesis that of the women who take main course science subjects in Colleges of Education a large majority have G.C.E. science qualifications in biology and take biology as their main course subject. If the physical science education of the future is to be improved, or even maintained, this self-perpetuating system of girls taking biology at school and in Colleges of Education and coming back to school to teach biology must be changed. It is not realistic to suggest that girls with only biology qualifications in science should be made to take courses only in physical sciences at Colleges of Education, but it is not unreasonable to suggest that by persuading them to take more broadly based courses in science their interest may be awakened in some aspects of the physical sciences and they will at least be prepared to broaden the range of their own future science teaching.

If there is such strength of opinion that science courses should be broader than they are, why have the more formal, narrow, specialist subject courses survived for so long? Several reasons are given. One is that the specialist course, for example the single subject honours degree course, has considerably greater status than the broader courses, the general honours or pass degree. Part of this status is due to the fact that quite often students who are not considered suitable for an honours degree are relegated to a pass degree course and this implies that the latter is inferior. Students in universities have also claimed that parents, teachers, and friends, unaware of changes which have taken place in universities and colleges, tend to give advice which is based on their own college situations and that this is often out of date. An important factor to which students have drawn attention, for instance in "Eighteen Plus" (+ 75), is that while those students who enter single subject departments find an immediate home where tutors and students have a single common purpose and he organisation is subject centred, those students who choose courses which bridge two or more departments have difficulty in finding such a stable and comfortable anchorage. We should be careful in planning our courses to ensure that all students who join us, no matter which of our courses, main, curriculum, or degree, they follow share equally in the climate of study which we hope to provide.

The Vice-Chancellor of Durham University, D.G.Christopherson, has pointed out, (+ 20), and the Hale report has agreed (+ 94), that many students tend to make their applications for universities and colleges to the departments of those subjects which they study at school in the belief that they are more likely to be accepted in these departments. However, there is ample evidence that many educational institutions are providing science courses with a wider scope and that gradually students are electing to join these integrating departments. One example will suffice. The University of Warwick offers a degree in Molecular Sciences. In this department it is felt that divisions of science are rapidly losing their relevance and that be continuing them mere differences of emphasis may harden into sharp distinctions which have no significance in the natural world. One of the principal objects of the department is to attempt to see the interrelationships of subjects and to appreciate the fundamental principles which underly them. It is hoped that students will see what they do as a coherent picture of lasting value which can be applied creatively later. The emphasis is on stimulating intellectual activity rather than the acquiring of a growing corpus of knowledge and this is typical of a new approach to science learning shown in many of the new, and in some of the old, universities.

Any attempt to advocate the broadening of science courses at college level will bring criticism, quoting as evidence the repeated failure of General Science courses with older pupils in schools over many years. In 1920 the School Science Review printed a now famous article, "Science for All" (+ 82), an eloquent plea for the introduction of General Science into schools to replace what was called "the limited amount of physics and chemistry that is now custimary". This plea has been repeated from time to time since then by many authorities, such as the Ministry of Education (+ 29,Ch.6), the Schools Council (+ 79,p5), the Science Masters' Association (+ 84,p.14), and by individual educationalists such as Tricker (+ 93,p11), Bruner (+ 11,p.26), and many others. Yet despite pressure and persuasion the number of candidates taking the General Science papers at "O" level in the Northern Universities Joint Board G.C.E. examinations, for example, remains very small as the following table for 1966 shows:

NUMBERS OF CANDIDATES BY SUBJECTS

N.U.J.M.B. Ordinary Level Summer 1966

| | |
|---|---|
| Physics .................... | 27931 |
| Chemistry .................. | 24159 |
| Physics-with-Chemistry ..... | 6097 |
| Biology .................... | 30241 |
| General Science ............ | 5111 |
| Human Biology .............. | 3231 |

There is no examination at Advanced level in General Science. In looking for reasons why schools offer so few candidates for General Science in the G.C.E., we discover evidence both from the examining boards and from the schools that the subject is not looked upon as an integrated science course but rather as a hotch potch selection of parts of the three syllabuses of physics, chemistry, and biology. The Oxford Board, for instance, actually prints its General Science syllabus (+ 72,p.38) in three parts headed "Physics", "Chemistry", and "Biology", while many schools with timetables showing General Science in the middle years divide the course into three sections which are then taught as separate subjects by specialists from the three contributary departments.

The objection which teachers so often bring against broadly based courses, whether they are integrated or not, is the difficulty in getting staff who are prepared to teach the whole course. This is a problem which can be solved only when the training of teachers is such that large numbers of teachers are confident enough and eager enough to broaden their own fields of science. The problem can be eased if the present science teachers with their specialist training are prepared to cooperate towards the attainment of a common goal. This cooperation will be achieved only if practising teachers are convinced that broader science courses offer greater educational rewards to both teacher and pupil and we will look to the products of our Colleges of Education and Universities to preach the doctrine of integrated science successfully. In an interim report of the Council for Curriculum Reform entitled "The Content of Education" an anonymous author offers a dramatic comment:

> "In many respects, increasing specialisation has made teachers as wise as owls in an ever-narrowing field, but as blind as bats over an ever-widening one." (+ 25,p.18).

While team teaching may, as yet, not be a practicable proposition for many schools, its use in Colleges of Education may offer an attractive and profitable means of fostering the integration of ideas in scientific fields.

In addition to the practical difficulty of getting teachers willing to teach General Science up to the sixteen year old level, there has always been the widespread criticism that it is unstructured, that the sections are unrelated, and I agree with this being a valid criticism of the courses proposed over the years as General Science. The main failure of these courses has been that they provided a thin covering of a very broad area of the field of science without showing what is a vital part of any science course, the interrelationships between the parts, the interdependence of all the fields of science. There have been two classes of children, the young and he less clever, for whom General Science has been considered suitable in many schools over the years. The general practice has been for t he brighter child, in the grammer school for instance, to move from General Science into one or two, and in the case of a small minority, into three, specialist science subjects, quite often physics and chemistry for boys and biology for girls. There is no obvious reason, however, why the bright child or the older child or even the adult should be directed to single subject sciences, provided the broad courses can be made intellectually satisfying to more able and more mature minds. It is my contention that suitable courses have rarely been offered in the past and that if they were to be offered they would prove both popular and profitable.

The two main problems which face us in preparing our integrated science course seem to be the selection of those parts of science to be included, and how to s structure the course so t hat the relationship of the parts is meaningful and obvious. Perhaps, however, these two problems can be solved as one, and this I hope to do. I suggested previously that while ideas, approaches, methods of working, and ways of thinking and posing and solving problems are more important than the mere acquisition of information, students must have some information and knowledge to work with. The question arises as to whether there is a corpus of scientific information which any educated person should be expected to know, and if we find that our students have not acquired it before they reach us can we and ought we provide it. If we argue that science should be taught for its own cultural value, and I have done this in an earlier chapter, are we suggesting that there is an agreed minimum core of information needed to satisfy this cultural demand? I think that if we asked a parallel question, say of classical literature, it would be very difficult to draw up a prescribed list of books which it would be essential to have read in order to qualify as a cultured man. But it would be very difficult to qualify a person who had never read any of Shakespeare's plays, and in the same way I think perhaps the test of scientific culture might well be not by a positive list of what should be known but rather the negative test of there being no enormous areas of ignorance. I believe that in a single subject course within the sciences, in physics for instance, there may be an argument to support the defining of a body of knowledge which the student should acquire, but in a broad course of the type which I shall propose, which will include aspects of almost all branches of science, it is neither possible nor desirable to draw up an inventory of essential factual content. This is not to say that once the areas of science which our course will investigate have been marked out, there will not then be essential information as well as ideas and techniques without which a study of these areas should not be carried out. In these areas our student will be well versed and, knowing the relationships which these areas have, one to another, and seeing how the information has been used to convey ways of approach and exchange of ideas, he will, we would hope, extend the range of his attention to other areas when he has further time to do so.

How, in practical terms, is our course to be designed to satify the two needs of natural integration and purposeful selection? The need for integration arises in traditional science syllabuses because we have taken apart the naturally occuring situations, separated out all the individual factors which ordinarily go to make up these complex situations and taught them in isolation. Often the pieces have not been put together again to show where they originally came from. There is no need for synthesis or integration if we do not, in the first place, break down an already integrated complex of scientific potential. An example will illustrate this. One of the most obvious places for me to begin an investigation is with myself, with some particular aspect of my own situation; for instance, I might consider the problem of keeping myself warm as I sit here at a desk in a library carrel on a cold February day. My comfort depends on so many factors and many of them are interrelated, the food I have eaten, the clothes I am wearing, the humidity of the air, the ventilation, the heating provided, the weather outside, the brickwork, the glass in the window panes, and perhaps many other items. In a traditional science course these factors would, no doubt, all be dealt with in their own sections, and no doubt reference might well be made, though not necessarily, to their effect on keeping me warm. Somewhere along the line, for instance, surface tension will be studied from basic principles and capillary rise in glass tubes measured, when quite probably the damp course in a brick wall will be mentioned. In another part of the course latent heat will be studied and it will be pointed out or demonstrated that evaporation causes cooling and reference will be made under this heading to perspiration. If, however, instead of having a course which starts over and over again with isolated basic principles, we have a course in which one of the starting points is the investigation of keeping me warm there is no problem of integration of the principles involved.

There may well be different problems posed by having a course where the starting points are complexes of many scientific principles, and one of them may be that the teacher feels that such a course is not as logically compiled as the traditional course and that there are many gaps in what might be termed "fundamental Science". I do not think that it matters in the least that it is not neatly and tidily categorised not that there are gaps; there must be gaps of one form or another.

One of the values of beginning with a large complicated problem is that it allows different aspects of it to be folloed up with different emphasis and concentration, since those factors which interest one group may not equally interest another, but there is plenty of choice. Another virtue is that one of the essential skills of scientific investigation is the ability to extract from a multiple problem situation the individual problems, to isolate them, identify them, and investigate them in relation to the other problems also present. This very valuable practice is missing in the traditional science approach which usually offers only one problem at a time.

One of the objections which may be levelled at the "complex" approach is that some or many of he factors which are involved may require for their investigation information which the student does not possess. This is, of course, true, and part of the work for the students will be to acquire the information necessary to proceed with an investigation. At this stage the student will be following the same path as students in traditional courses in that he will be looking at basic principles and collecting information about them in so far as he needs them. I have found that students looking for information in order to apply it to a problem on hand are much more satisfied in what they are doing than those who are gathering information because it is "fundamental science".

The second main problem in the construction of our course was said to be the selection of areas of study. Remembering that we are trying to satisfy two needs, one of an overall balanced survey of the whole field of science, and the other some investigations in depth into selected areas, we must arrange that the starting points must be chosen so that they will give scope for recognition and appreciation of a fully representative selection of scientific work, without involving needless repetition. Much of what can be learned in any one situation can be learned in any other; the way in which evidence is collected and processed, features of setting up and carrying out experiments, the appreciation of the validity of conclusions, for example, having been concentrated upon in one or two investigations can be accepted by transfer in other situations.

There would appear to be no "right" or "wrong" selection of topics, in my opinion, with which to begin the section of our course, provided that in the end, in the timeavailable, the student is confident that he can carry out investigations in any area of science he may find himself, capable of seeing that there are methods of approach, ways of investigating, and forms of communicating which are common to all branches of science.

If it is argued that what is being suggested is simply a general science course of isolated topics being taught by rather undisciplined methods, I would answer by emphasising that investigational methods need not be uncontrolled, and much of our course will be directed, and also that the selected topics will be linked together with constant references being made to the relationships between the topics. The linkages and interrelationships will be environmental, that is to say that the course will be based on what can be initially examined and investigated directly. Much of what needs to be done can be done in a single localised environment at first but when its potential has been fully exploited variety and breadth can be introduced by extending the environment in distance and time. The advantages of the environmental approach and how it satisfies the needs of integration and purposeful selection are considered in the next chapter.

CHAPTER SIX

## THE ENVIRONMENTAL APPROACH

Our need is for a method of studying science which will satisfy these conditions: it must give a balanced picture of the whole range of science; the areas in which the student can work to an intellectually satisfying depth must be selected within an obviously integrated structure; the course must allow for the wide variety of interests and science backgrounds of the students; it must be particularly suitable for those who are going to teach.

If we are looking for evidence that the traditional methods have not succeeded in holding the interest of our students we have only to read the damning indictment to be found in the Crowther report:

> "An observer of English education can hardly fail to be disturbed by the large number of able boys and girls who lose their intellectual curiosity before they have exhausted their capacity to learn... Where so many patently lose interest in developing powers they undoubtedly possess, and in which they used to delight, it seems to us that the fault must, inpart at least, lie in the kind of education they are offered" (+16,p.391).

That this wretched situation should exist in the field of science where so many riches are available to attract the interests of our pupils and students seems almost incredible.

The environmental approach uses the fact that science can be studied by having direct recourse to the prime source of information, the immediate environemnt. Many subjects can be studied only by using information acquired by others, but science need not be restrained in this way. By using that which is available to teacher and student as raw material it is easy to see that science was built up in answering or trying to answer questions which arose naturally. By starting with the world as we find it we hope to lay proper emphasis on our principal aims, to learn about the natural laws and their effects, to learn the methods of scientific thought and investigation by using them, and to gain an appreciation of the influence of the environment on man and the influence of man on his environment. The importance of giving due consideration to the role of the environment in any teaching situation has been emphasised by many authorities, the Ministry of Education (+ 29,p.2), the Association for Science Education (+ 4,p.9), Bruner (+ 11,p.39), O.E.E.C. (+ 71,p.7), and others. By allowing ourselves to be involved in whatever is available we emphasise that nothing is too small and nothing too big for scientific investigation, that science is all embracing, and that subject divisions are conventions which, while often necessary for reasons of organisation, have no foundations in the natural world. On the other hand if we draw on our own direct experience for starting points for investigations there is much less risk of these areas appearing disjointed and unconnected, since their interrelationships and interdependence are apparent to us by observation.

It is obvious from the start that it will be quite impossible to cover all the ground of the science which even the narrowest interpretation of the immediate environment could present to us, and we must show our students that a wise distribution of interests and efforts is necessary if the course is to be efficient and profitable. We shall point out that our environment is limitless, since if we move we extend it. If such movement can carry us not only to surroundings where the factors are somewhat different but to regions where they are considerably different then we shall gain by variety. There is great need for urban and rural populations to know more about each other's problems and satisfactions.

We shall be partly improving this situation if we are able to show that our investigational approach is equally applicable to the many different environments that prevail. It is sometimes argued that by adopting an approach which looks only at its own surroundings a parochial view of science is being encouraged. I reject this on the grounds that, no matter what the surroundings may be which give rise to the initial problems or investigations, the principles involved in the solution of the problems will always be the same. We hope that our course will encourage our students to look for a good basis for their own science teaching in whatever environment they may find themselves when they start to teach. There is, I think, great value in having a form of teaching science to students which is basically similar to the form which they will use in schools. At least it impresses upon them that they should not look upon school science as a universally accepted body of knowledge to be handed on to their pupils. One of the principles involved, which we hope our students will take away with them, is that which the Ministry of Education has phrased as "science being not only knowledge but a way of gaining knowledge." (+ 30,p.3).

Of course the students are to be told that we do not think that there is only one way in which science should be taught. Just as the various science teaching authorities in this country advised that the schemes produced and tested in the United States should not be introduced as they stood in schools in this country, but should be used to help us to think fundamentally about our own approaches, so we should encourage our students to examine carefully their own teaching situations when they are appointed to schools and should consider how far the suggestions on science teaching made to them at college need to be modified.

In our course we need to be quite clear about the role of the tutor. From time to time there is need for the giving of information by the tutor to the students where this information cannot be obtained directly or when the time involved in its acquisition would be disproportionate, but even in these circumstances this exchange should not be in the nature of what the O.E.E.C. calls"ex-cathedra pronouncements" (+ 71,p7). I see the main task of the tutor as being the sustaining of the elements of surprise and wonder which are vital to scientific investigation. He should see that the work which the students do is not just repetition of what the teacher did or what the book says should be done and ensure that he does not ask the students to spend time solving questions the answers to which they know . If the teacher wants his students to use initiative and to be prepared to trust themselves to some intuitive thinking then he himself must be willing to do the same from time to time,,though, of course, most of what is done will be the result of careful planning and intelligent anticipation. It is perhaps too much of a platitude to say that the teacher must endeavour to get his students to think for themselves.

Any course which is environmentally based will be essentially experimental or practical. The word "practical" has so many meanings that some of them should be considered to avoid ambiguity. The Crowther report (+ 5,p.391) considered some of the uses to which the word is put and four of these have relevance to our situation. Work which students do can be said to be practical when its purpose is obvious and we must be certain that we make its purpose in our course clear to our students; work is practical when students are themselves involved in the physical operations and are not just passive spectators, and I have already underlined the need for this approach; practical work can take the form of invention rather then creation and for many people there can be just as much aesthetic satisfaction from the one as from the other, and scientific investigation offers a unique opportunity for the inventive mind to exercise its powers; a method of teaching can be practical rather than academic when it moves from the particular to the general, and our environmental approach uses this practical method of teaching.

As can be seen by consulting science textbooks, particularly in the physical sciences, over a period of many years, the commonest way of dealing with a science topic has been traditionally first, to expound a principle, then to verify or illustrate it, to give examples or applications, and then to follow with calculations or questions to test memory or understanding. In order to be able to benefit from this form of learning the mind must be capable of appreciating the meaning of a generalisation, and this usually, is associated with the ability to sustain logical progression. I suggest that the majority of people would benefit more if they were presented with learning situations which used the opposite approach, namely the consideration first of particular examples and the derivation of a rule or law or pattern from some common factor within the particular examples. It may be argued that by rejecting the analytical approach as we do in the environmental method we are penalising the clever or academic student, but there is no reason why this student should not use the method of synthesis with considerable success. If comparisons are made with university practice we should remind ourselves that few of our College of Education students would be capable of sustaining academic courses of the type common in university science departments. It has often been said that we should, in our science teaching, move from the simple to the complex, from the known to the unknown, but this is not always the best approach, since pupils and students are often confused by the many new starting places and because they do not know what they are aiming at when they begin a new topic. At least one American educationalist, Francis Freedman, is highly critical of this approach:

> "Every professional science book rests on the philosophy of starting with the known and going to the unknown. And this is the surest way to bore the children to death. Start with the unknown and work to the known." (+ 10,p.68).

Our environmental approach begins with practice in careful observation, first of large easily seen phenomena, progressing through diminishing size and time, until with direction and assistance our students look at and listen to and touch many things which previously they would have passed by without noticing. From such observation problems arise or are posed, and generally they are complex problems, since almost always many influences are present in a natural situation. The original problem has to be broken down and its solution requires a search for the principles which explain the various influences involved. This is a basically different way of starting from standard laboratory or classroom methods. This is the way I believe the scientist begins. It has not been uncommon for educationalists to suggest that young children could begin their science education by examining their immediate environment, but it is only in recent years that sophisticated adult scientists have concentrated on environmental research. An increasing amount of work is being done by physicists, for example, in situations where all the factors of the natural environment are allowed to continue while their effects are being studied. In this country a Natural Environment Council has recently been set up under the chairmanship of the Director of the Meteorological Office, Sir Graham Sutton, and in the United States the Army has instituted a research project in environmental scientific measurement which is concerned with the considerable changes which may occur with very small variation in equilibrium factors. It is becoming increasingly more appreciated that large scale classification of environments has little value in estimating what will happen to a particular organism in a particular microenvironment, whether it be man in the Arctic or a hop plant in Kent. The study of natural, domestic and controlled environments is no longer just an entry into the ways of science but is a vast field of investigation important enough to attract the attention of experienced scientists. C.W.Kilmister, who in "The Environment in Modern Physics" applies environmental thinking to the sphere of atomic physics, says:

> "It is commonplace in physics to study systems interacting with their surroundings, and indeed the whole basis of scientific method is to divide a complicated problem into parts which interact with one another and then to concentrate on one part of the system and make simplifying assumptions about all the others which we shall call the environment." (+ 49,p1.)

How shall we use the environment in our course? We could use it simply as the source for topics which could be isolated and examined from the viewpoint of the physicist, the biologist, the geologist, and so on. This could be interesting and profitable and would have the merit of having evidence first hand, but it would really only be a general science course with a particular environmental form of selection. The rather different approach which I am advocating is that which examines environments as systems of variable factors, systems in equilibrium but in which the conditions of equilibrium change constantly. It is perhaps at first not obvious that we are studying a continually changing environment but physical and biological conditions change not only over long periods of time but often very rapidly and not only are conditions different in places widely separated but often two locations very close together have widely different environments. We are concerndd largely with change, with the constant gathering, analysing, interpreting, and presenting information and conclusions. The key to most of our work is energy exchange which involves considerations in almost all the recognised sections of science.

Why should we restrict our course to a particular approach? Because, I think, it represents an approach which satisfies all our requirements, and in particular, offers opportunities for investigations at all levels of difficulty, real investigations found within a stone's throw, and it has all the qualities of integration that we have been looking for. An objection may be brought that what is being proposed constitutes a return to heurism with its known faults. The answer lies in two points, firstly that return to some of the principles of Armstrong's heuristic method is probably desirable since our science teaching over the last quarter of a century has drifted into stagnant waters and we have a generation of children and students, many of whom see little to excite or even interest them in the world of science, and secondly that we do not intend to allow our students to wander round alone to find their problems casually, nor to become bogged down in unprofitable or tedious digressions, nor to miss opportunities which arise close at hand. The content and complexities of the environment will first be explained to the students who are shown how investigations may be likely to arise and which will probably be fruitful. The general structure of the course is planned beforehand, but with enough flexibility to allow for group or individual initiative. The teacher himself will have considered the areas in which he expects the work to take place, and he will often have to provide problems at the beginning for some or all students if they find this way of working strange. As time goes on he expects more ideas to be provided by the students themselves. One problem facing the teacher is to decide how far to allow what he judges to be unprofitable investigations to continue. It would be wrong to allow students to spend their time always searching and never finding, but it is essential that sometimes they be allowed to find themselves at the dead end of failure.

While our environmental search may have begun differently from standard courses we must keep a true perspective about it. It is a science course and much of what is being done at any instant will look much like what other students on other courses are doing. Our investigations are concerned with getting back to first principles and these are the same no matter how they are arrived at. The weaker students will find themselves engaged in the simple elementary stages of scientific investigation, and when we have finished it is unlikely that any of us will have extended the frontiers of knowledge.

One thing which we hope to do in our course is to encourage work in physical science, not just for its own sake but because it is necessary in order to solve problems. I am sure that one of the reasons for the relative unpopularity of school physics is because it has so often been concerned with the determination of physical constants which did not seem to have any meaning for anyone.

Any investigation concerned with examining all the factors involved in a naturally occurring situation must take into account the physical factors, and information from the spheres of physics and chemistry will have to be collected and understood before the investigation can proceed. In this way it is hoped to extend the interest and background of our students in the physical sciences. An important point is made in Platt and Griffiths' book, "Environmental Measurement and Interpretation", (+ 73), that the true value of much physical measurement is seen only when it is placed in full environmental context, where the importance of the contributions lies not in the absolute but in the relative values of the quantities measured. For instance, the importance of water in the natural world is due to its low chemical activity, its high surface tension, high ionization, high latent heats, high specific heat anomalous expansion, high power of solubility and so on. The actual values of these measured quantities are important only when they are placed alongside the values for other materials found with water in real situations in either natural or controlled environments. These real situations, we say, give us the best conditions possible in which to carry out science studies.

Any course which emphasises the desire to encourage thinking and claims not to worry about "covering the ground" leaves itself open to the criticism that while the student may have enjoyed himself and may have understood what he was doing while he was doing it, he will finish the course without having learned anything rigorously and that in a short time he will have forgotten what little he ever knew. I reply in two ways. First by referring again to Nowell-Smith (+ 66), who has pointed out that to be a scientist is not to know what Galileo knew and more but to be able to understand how men like Galileo thought; and second by referring to Eric Rogers, Nuffield Physics Organiser, (+ 78), who claims that traditional methods of rigorous science teaching have produced a generation of adults who did not understand science when they were at school and now can remember nothing of what they were supposed to learn. We are going to offer our students a different approach to science which will demand of them more thinking and more initiative , in the hope that they will understand and remember.

The approach to an environment will begin, I think, always in the same way. After a preliminary general survey, a single organism or object is selected as the focus and an instantaneous picture is drawn of all the factors which affect the organism at a single point in time at a single point in space. The factors are identified as far as possible, and examined as accurately as our skills and instruments permit. Our study of the same organism can continue in the same place over a period of time and the changes in environmental factors observed so that conclusions can be drawn about relationships between the factors themselves and between the organism and the changing factors. Alternatively we can extend our study by examining, at the same time, a number of similar organisms in different places, perhaps close together or perhaps widely separated. ~~A~~ Although the term ecology might be thought to cover this type of work it will be seen when Part One of the syllabus is discussed later that I wish to give a much wider meaning to the term than that usually employed in biological discussion.

What kind of organisms or objects do we intend to consider and how many kinds of environment would we want to examine? There are four general types of environment which we are likely to meet:

1. Natural environments in which the influemce of man is either absent or of little significance, for example, a moorland , a seashore, or a forest, and in these the organism chosen would be an animal, a plant, or a piece of mineral, and the factors studied would be the physical and biological influences bearing on the object.

2. Rural situations, where man's influence is quite considerable, for instance a cattle farm, a fruit orchard, or a planted forest, and where the chosen focus would be a plant or an animal and the factors involved physical, biological, and agricultural.

3. Urban life, where man predominates and where he is the selected object and where the environmental factors examined are those which affect him. Here we must be careful to remember that we are concerned only with scientific enquiry, and sociological or psychological topics are to be excluded.

4. The urban environment, dominated by man, but where the elected unit for investigation is not man but a plant or an animal. We might find our unit in a

suburban glasshouse or garden, in a city wasteland patch, in the trees in a park, or among the various domestic pets found in many town houses.

These four environments will be discussed in greater detail in Chapter 9 when comments are made on Part One of the syllabus. I think that all students should work in all four general environments. Most of our students will come from urban communities and more of their experience and observation will be of people than of plants and animals or landscape structure, and we should buid upon their knowledge of familiar environments and at the same time encourage them to find new experience and interest in other areas.

With regard to choice of natural areas in which to work this will usually be restricted or even determined by the geographical position of the college, the money and facilities available for travel to other localities and many other factors. It is by no means necessary, in any case, to have had working experience in a large variety of natural environments. While it is useful and advantageous to have experience of more than one area, especially if they can be geologically or biologically very different, many of the points we to make about direct scientific investigation can be made in a single environment.

Our empirical, environmental approach cannot be judged properly until those trained by it have grown older but by trying to capture the interest of the students by offering them opportunities to exercise original thinking, by eliminating much of what has appeared to students in the past to be purposeless, and above all by concentrating the students' attention on their own immediate personal experiences, we should surely be more likely to leave our students with a more lasting and truer picture of science.

Let us then summarise the ways in which our environmental science course is going to differ from traditional College of Education courses:

1. There will be no subject boundaries in our programme or in our practice.

2. The whole range of all sciences will be available to us and we shall become involved in most of them.

3. While we shall give an appreciation of the scope and methods of science as a whole, the areas studied in depth will represent only a small fraction of the breadth of science, so leaving large areas unstudied.

4. The starting point of all work, and the unifying influence will be the immediate environment, inside or outside the college, and the environment will be extended as required.

5. The environment will be used not merely as a source of topics for study but will be itself a subject of study, wherein the reactions and interactions of various factors are observed and measured.

6. The problems and investigations which arise will be examined in their entirety, even though many of them will be complicated. The progression will be from the unknown to the known, fsom the complex to the simple.

7. Not all students will work along exactly the same lines. The science backgrounds and the interests of the students on our course will be much more varied than those of students on more traditional single science courses, and they will need to be given much more freedom to pursue individual preferences.

8. There will be more emphasis on the way in which scientific knowledge is gained than on the remembering of factual information, though the value of acquired information will be recognised.

CHAPTER SEVEN

RELATED SUBJECTS

In our consideration of the content of our course in environmental science we have, up to the present, referred only to those areas which are normally included in the sciences of physics, chemistry, and biology, but since I have suggested that the approach should be one which did not, in the first place, concern itself with subject boundaries, there is no reason why only three sciences should contribute to our field of study. I now propose to examine some other subject areas to see if they contain material which should be considered for our course.

The wider we range in our considerations the greater will be the difficulties in preserving the structure of our subject and in preserving enough depth of study in sufficient numbers of areas. While one could adopt an attitude which claimed that knowledge is universal and an environmental approach could be completely free ranging, I do not favour this, and so I emphasise that the course which I propose is a course in science and anything we use from these other subjects can only be included if it constitutes a piece of scientific study.

I use as a simple definition of the meaning of scientific study at this level the one given by the Association for Science Education:

> "No matter which branch of science is being studied, it can hardly be called science unless, within the limits of the pupils' ability, it embraces observation, hypothesis, verification, and the formulation of a general law." (+ 60,p.8).

Sometimes the name science is given to studies which involve only observation, collection, and classification, or sometimes to the learning of a craft, and these I would exclude from consideration since they do not satisfy the definition which has been chosen as our criterion.

---

The second condition to be satisfied before any area of scientific work can be considered for inclusion in our course is that the work arises naturally from a study of the students' environment during the course. It seems natural, therefore, to examine first the subject called Environmental Studies, a subject which has appeared in curricula of Training Colleges and Colleges of Education for many years, and which is now being offered by some of the newer universities. It will be necessary to show how much our subject of

Environmental Science owes to the older Environmental Studies and where the two differ. The Handbook on Teacher Training, published for the Association of Teachers in Colleges and Departments of Education, for 1968, (+ 7) shows that Environmental Studies is offered as a main course subject in eleven Colleges of Education in England. The subject does not normally appear in secondary schools but is often shown on the timetables of primary schools. Two universities, Lancaster and Loughborough, have departments of Environmental Studies. Two Colleges of Education, Northumberland College at Ponteland, and Portsmouth College, offer a main course in Environmental Science, but no university has a course of this name. While there is considerable variation in detail between the syllabuses in Environmental Studies issued by the various Colleges of Education, all the courses have much that is common and an inspection of one of these courses, namely that at Loughborough, will serve as an example.

The features of the environment which the Loughborough main course sets out to study are given as "geological, geographical, biological, historical and architectural," although it is emphasised that studies will not be regulated by conventional subject boundaries. The second section of the syllabus gives eight groups of formal studies which will be followed and of these four could be said to have scientific connections. They are:

"(i) Classification of rocks: their characteristics and distribution: associated scenery and soils.

(ii) Local variations in weather conditions. Effects on plant and animal life: horticulture and agriculture.

(iii) The structure of specific plant and animal communities: the relationships within them and the factors responsible for the structures and relationships.

(iv) History of farming. Twentieth century farming and horticulture. Use of animal and plant breeding to assist in man's survival." (+ 54).

Section (i) draws our attention to the appearance of rocks and soils in any environmental study. Certainly some work on rocks and soils would seem to be required of us but if it were to be a scientific treatment we should have to think of it rather differently from the way it has been outlined above where observation and classification would seem to be all that is being considered. If we can put the name of elementary geology to this work we shall have to ensure that our geology contains the elements of problem and conclusion which we have required of our other work. This will be borne in mind when the syllabus is drawn up in greater detail.

Section (ii) also shows us an area which might well interest our students, particularly as it advocates investigation into the effects on flora and fauna of local weather variations. This I consider to be in the same spirit of enquiry which we hope to foster in all areas of our course, and some meteorological work, not just however observing and recording weather changes, but studying the effects of changes over distance and time on not only the biosphere but on the physical environment in particular, should be included.

Section (iii) includes the kind of work we should expect to find in any case in the biological side of our course and so offers nothing new for our consideration.

Section (iv) brings in horticulture and farming, though rather from an historical viewpoint than from a scientific one, but it does open up the big question of how far, if at all, these areas, treated scientifically, should command a place in our course. Later in this chapter I shall consider the subject of Rural Science so I propose to leave horticulture and agriculture till then.

At this point the course of Environmental Studies moves into areas which could not be considered to have any scientific associations, the other four sections being concerned with the development of rural and urban communities, environmental planning, and the history of social developments.

If we turn to the course in Environmental Studies offered to undergraduates in the University of Lancaster we see quite a different interpretation. Here the subject is approached as part of a geography course but with a much greater emphasis on measurement than has been usual in the past. The prospectus says:

> "In as much as science proceeds from the description of state, to the discussion of the rate of change, the evolution of the landscape is not now merely to be described; it must be measured." (+ 97,p.52).

Here then is the same emphasis on the importance of knowing how the environment is changing that I tried to convey in the last chapter. If this geography is concerned with measuring conditions and changes in the physical world and the effects these changes have on soils and vegetation, on animals and man, then it must have a place in our scheme of microenvironmental investigation. We have here also an indication that in our course, which depends on the "field sciences" for much of its data, measurement and interpretation play an important part and any ideas we might have had that our course would be mainly descriptive are by this time dispelled. I have said that many of our students, particularly the women, are weak in mathematics, but they will need some facility with numbers and some appreciation of quantitative work, so we shall have to be prepared to help in this field.

An examination of the Environmental Science course presented by the Portsmouth College of Education shows that there is little fundamental difference between it and the Environmental Studies courses of other colleges. It may well be that there are different emphases in the approach and in the teaching which cannot easily be described in a brief outline but there seems to be little in the course which we could use which has not already been mentioned.

I am a tutor in the department of Environmental

Science at the Northumberland College and any discussion of the syllabus of that college would involve much repetition of what has already been said, so none will be attempted. The course which I am proposing in this thesis is not, however, that which is being taught at Northumberland College, for two reasons, though of course there are points of similarity; one reason is that as I am not the head of the department the college course is not determined by me and is, of necessity, not the same as the one I would construct; the other reason is that the course I am proposing in this thesis is one which I think is best suited as a basis for any college to use as a starting point, whereas the course at Northumberland College is geared to the particular requirements of the college. The setting of the college, its size, its newness, the history of the growth of the department, the interests and qualifications of the staff of the department, and the fact that, up to the present, it has trained teachers mainly for primary schools, are among the factors which have helped to mould the Environmental Science course, which is still being revised since it is not yet five years old.

In 1970, for the first time, Environmental Science will appear as a subject in the General Certificate of

Education, when it replaces General Science in the Cambridge Locals examination at Ordinary level. The syllabus presented by the Syndicate is directed particularly to those pupils whose science education will end at this level, and contains topics in physics, chemistry, biology, astronomy, geology and meteorology, based on everyday experiences. The examiners give the three ideas which influenced the construction of the syllabus; the relationship of man to his environment; the earth and its situation in the universe; the use made by man of natural resources both of energy and materials.

The very detailed syllabus, running into sixteen pages, is laid out in its separate subject headings, and nowhere is any indication given that an integrated teaching course is envisaged, though one might expect this interpretation from the title of the subject. A comparison of the Environmental Science syllabus with the General Science syllabus which it replaces shows that the new physics part is very nearly the same as the old one except for the addition of a quite substantial section on "Modern physics"; new sections on astronomy, geology, and meteorology have been added; the chemistry section has been rewritten but the content remains much the same as before; the biology section has been considerably revised, "Biology of Man" and "The Life of a Plant" being two of the three themes. The third theme is called Man's Environment", with the topics appearing here which did not also appear in the General Science syllabus being pest control, conservation of animal and plant life, and World Health, none of which is treated in any great depth. The new syllabus seems to be so similar in approach to the old that it does not appear to offer any fresh ideas in the furtherance of our discussion.

"Local Studies" is the name given to another type of study which involves field work and which may offer us ideas worth consideration, though this kind of work is not so common as it was fifteen or twenty years ago. The Ministry of Education pamphlet, "Local Studies" (+ 27), was produced in 1948, following the Geographical Association's "Local Studies" of 1946, (+ 39), and these are still the authoritative publications on the subject. The emphasis in the Geographical Association brochure is on citizenship and is aimed at the early years of the secondary school. It does not advocate the presentation of generalisations and ideas at this stage on the grounds that this is psychologically unsound for children of this age. While mention is made of the value to natube study and more formal science of the study of the pupils' environment, the topics detailed for the course and the method of their presentation show no evidence that any work of a scientific nature, as understood by our previous definition, is contemplated

The visual unit, prepared by the Ministry of Education and called, "Local Studies", consists of a sound film, two silent films, eight film strips, a wall display, a cine-panorama, and a handbook, and while in all of these there is very little which is of direct application to any course of science, our attention is drawn to this type of presentation involving different media, which we might well bear in mind when we come to consider how the results of our own investigations are to be presented. Again we are impressed by the importance of using the best and most attractive methods of presentation appropriate to the circumstance, in this case group communication. As in stage presentation the audience plays an important part, and in all our work we should remember how powerful is the satisfaction which can arise from the intercommunication of personal achievements between the several members of a group working round an integrated theme. One quotation from "Local Studies" is particularly worthy of our attention, as it is one of the few references in official publications to the importance of photography in field work:

"Photography is almost a necessity to local studies. It recalls winter in summertime, strengthens field work, and brings the landscape indoors. (+ 27,p.32).

The National Rural Studies Association published in 1963 a small book called "Rural Studies" (+ 61) which consisted of a survey of the facilities for the teaching of Rural Studies in secondary schools in England and Wales. A study of this booklet will reveal that Rural Studies is much more widely taught than is generally realised and also that there are more different names for these studies than probably for any other. Table XXII (+ 61,p.30) shows that twenty different names including Rural Science, Horticulture, Practical Biology, and Natural Science, are used within this area of study. How much of it is science and how much of it is envrionmentally based are questions we must try to answer from the many different viewpoints advanced. Table III in the same publication (+ 61,p.14) shows that while Rural Studies, in one form or another, was taught in very few grammar schools, only 5%, in 1963, pupils in more than 41% of Modern schools in England

and Wales carried out work of this kind. Surprisingly the book also shows that there is no evidence to suggest that the subject tends to be offered to the less able children. The large number of school gardens and greenhouses and the increasing number of pupils entering G.C.E., C.S.E., and other examinations in Rural Studies indicates that the subject is a growing one.

While the management of school gardens and the keeping of animals have rarely been practised in grammar schools, agriculture departments in universities have recognised the academic value of study in these areas of knowledge, and it is difficult to understand why they have been ignored in so many schools. The handbook of the Faculty of Agriculture of the University of Newcastle upon Tyne (+ 99) shows that the Agriculture Department has been part of the university since 1891, and that there is no doubt that the work which is done there represents scientific research. There are chairs in Soil Science and Plant Science and the subdivisions of the course spill over into biochemistry, geology, zoology, and chemistry, and the outlines of the content of the courses show, of course, the essentially scientific nature of the work.

It would seem desirable that an environmental science course at any level, at school or at college, must include some elements of the scientifically based aspects of gardening and livestock keeping. Perhaps the attitude often found among teachers of physics, chemistry, and biology, that horticulture and agriculture are not "real sciences" may stem from the way these subjects have sometimes been treated in schools rather as crafts and skills, but there is no reason why misconceptions should be allowed to continue, and by including these aspects of science in our course, perhaps we shall be helping to correct the lack of balance.

Perhaps the most widely read of the standard works on Rural Studies is that written by Carson and Colton, (+ 13) and from this book we may select some ideas on which to build parts of our course. The authors say:

> "Rural Studies is a practical subject, involving the crafts of gardening and livestock keeping, and including the study of farming and the countryside, biology and natural history and the science associated with horticulture and agriculture." (+ 13, p. 3).

We must take care to remember that from this wide field of possible activity we intend to call only on those sections covered by the last phrase, "the science associated with horticulture and agriculture", and then only insofar as they are associated with the environment being used for study. In listing the values of Rural Studies Carson and Colton give as their seventh item that the subject "provides good science teaching opportunities" (+ 13,p.7), and these are indicated later in the book when they emphasise that Rural Studies should allow no "hit-or-miss" attitudes but there should be:

> "...a scientific, objective, attempt to observe phenomena, calculate factors, estimate results, and measure achievements." (+ 13,p55).

This is in accord with our stated objectives. The authors advance as one of the aims of the subject the demonstration of man's control of his environment for his own ends, and this, they point out, is a scientific activity. Gardening, the authors claim, provides an opportunity such as is available nowhere else fro real biological experiments, not just demonstrations of facts known to the pupils, and for seeing the results, in practical situations, that scientists have obtained in breeding plants and animals. It is also pointed out that the school garden, the greenhouse, the animal house, are all sources for scientific investigation into topics in physical science such as transfer of heat, electrical appliances, chemical analysis of soils and fertilizers, and so on, and this location of problems in real situations agrees with our previously stated principle that the situation should first be found and the principles discovered from investigation. Throughout the book there is the attitude that biology without gardening and livestock keeping is incomplete and certainly the feeling of traditional biology being book-ridden and dry has been echoed not only in this country by authors such as R.F.Morgan, in "Environmental Biology", (+ 58), but also, as we have seen in a previous chapter, in the United States.

It is understandable that advocates of a particular science subject should be enthusiastic and persuasive, so perhaps we should look outside agriculture and rural science associations for support for these subjects. This is not difficult to find. In dealing with education and the countryside the McNair Report on "Teachers and Youth Leaders" (+ 26) supported Rural Studies teaching:

> "Gardening, including the care of animals which usually goes with it, is of great educational importance. It should not be considered from the point of view of schools, as any more a rural than an urban pursuit." (+ 26,p.135).

The Ministry of Education pamphlet No. 35, "Schools and the Countryside," (+ 28) explains how, due to its growth as a craft and due to its need to be economically self supporting, gardening has often been taught as a craft and suggests that it should be taught to show "the more recent applications of scientific principles". (+ 28,p.42).

In 1958 the Science Masters' Association publication "The Teaching of Science in Secondary Schools", in a chapter called, "Science in Rural Schools", discussed briefly the school garden and the keeping of livestock, but with no great enthusiasm, and in fact it was suggested that, in grammar schools, general science would be better for the pupils, (+ 84,p.231). However, in 1967, the same association, by this time the Association for Science Education, published "Teaching Science at the Secondary Stage" (+ 4), which contained a four page section titled "Rural Studies", and here the activities of animal husbandry, beekeeping, and crop growing are encouraged. Many Local Education Authorities have produced their own publications and helped to increase the teaching of Rural Studies, for instance by appointing County Organisers. Hertfordshire County Council, for instance, in collaboration with the Teachers' Rural Studies Association, published, in 1966, a "Rural Studies Handbook" (+ 41), of some hundred pages, and the outline of the facilities provided and the indication of the standard of work expected are evidence that the subject is looked upon as one of considerable educational importance.

The last related subject we turn to in this chapter is called "Field Studies". Perhaps the most authoritative and forceful argument for the inclusion of field studies, and we accept the term as being all science which is pursued out of doors using natural materials as the primary source, is contained in "Science Out of Doors", prepared in 1963 by a Study Group of the Nature Conservancy, (+ 62). The report is not just a plea for a reappraisal of field studies, but is also a plea for a new look at science education in general. The further education and re-education of science students and later of science teachers is considered essential and full benefit, it is argued, will be gained from this re-education only if the original training was by enquiring and experimental investigation. Although the report is primarily concerned with the biological and earth sciences it stresses the need to allow topics to be pursued wherever they lead across the boundaries of conventional science divisions, and it insists that scientists from all disciplines, including physics, chemistry, and technology need some time in the field during their training. Field work, the report claims, is essential as part of everyone's liberal education, so that the future generations may understand the need for a wiser use of land, water, wild life and other natural resources, and so that urban and rural populations may be brought to a closer understanding of each other.

There are difficulties peculiar to the pursuit of field studies, difficulties of time-tabling, of transport, of bad weather, of seasonal variations, of examining, of staff inexperienced in the field, and so on, but in a College of Education, where the organisation is usually more flexible than in a school, these difficulties should be vulnerable to strong thrusts of enthusiasm. The image of much bad science taught under the title of Nature Study needs to be swept away and should not be allowed to influence adversely our assessments of the value of these other forms of science teaching now being considered.

The subjects mentioned in this chapter all claim to be engaging more attention and to be spreading their influence. They all claim to be taking a closer look at the fundamentals of science teaching, and it seems that they all deserve serious consideration when we build our programme of environmental science. Areas in which students can work in some depth depend very much on the apparatus, materials, and facilities which we provide. If, for instance, we wish to follow up work in plant science or in animal husbandry we shall have to provide greenhouses, gardens, animal houses, and the like. These facilities would be used in two ways, first as controlled environments where investigations can be found, and second as practice areas wherein the basic principles of horticulture and agriculture can be learned in order that the investigations may be pursued. While I have argued that there should be no subject barriers in our work, and that investigations should be free ranging, we must realise that for those areas of scientific enquiry where specialised apparatus and facilities are needed decisions must be made whether or not to include them in the scope of our course.

I think we should not exclude from our course any large area of science which we are likely to encounter frequently and naturally in the examination and observation of our chosen environments. So it seems to me that elements of geology, geomorphology, meteorology, pedology, and horticulture, for example, must find a place in our planning. It does not seem in the least wrong to me that we shall select from certain areas of science only those parts which we need for our immediate use. There may be those who would argue that this makes our course superficial, but I would claim exactly the opposite, that by selecting only a small part of several science subjects and putting them in close association in particular environmental situations we are satisfying all the criteria of serious depth study in science.

In addition to those parts of physics, chemistry, and biology which will be needed I consider the following areas from those discussed in this chapter to be desirable for our course.

1. Those elements of geology which deal with the material of the earth, the forces which shape the earth, and the record of the earth's history.

2. The parts of hydrology and meteorology needed to define and understand conditions and energy exchange in the atmosphere.

3. The scientific aspects of horticulture; the use of plants, growing media, fertilizers, pesticides, and herbicides in open and protected cultivation for qualitative and quantitative experiments.

4. Examination of the effects on man of some large

scale agricultural activities, for example, forestry, fisheries, intensive farming methods, improving of strains.

5. Small livestock management: the use of, for example, beehives, aquaria, small mammal communities, as controlled environments.

Some areas of science are missing from the proposed course. One of the largest of these is astronomy. No doubt a knowledge of the place of the earth in the universe is highly desirable, but astronomy has been omitted on two counts, one because we shall very rarely need astronomical information in any of our investigations, and two, because for most of ~~us~~ our students a considerable amount of purely theoretical study of physical laws and mathematical practice would be involved before astronomical study could begin, and this seems out of proportion to the gain. Those areas of local studies and environmental studies which could be termed sociological or historical have been omitted although often the line of demarcation between them and science is difficult to draw. For example, geological study of landscape development can lead very easily to land usage and settlement. In situations like this I have not allowed extensions to take place from areas which are recognisably definable as science.

In this chapter I have tried to define the outer limits of the course which I am to outline, to indicate those areas of scietific enquiry in which we expect to work. It is now time to consider in particular that part of the course which comes under the heading of the Physical Sciences, and to see what role this part should play.

CHAPTER EIGHT

# THE CONTRIBUTION OF THE PHYSICAL SCIENCES

While this thesis is in general concerned with the presentation of a broad course in science, it has a particular reference to the role of the physical sciences in the course. First let us consider the attitude towards the physical sciences which our students have when they arrive. Table 17, p.228 of Appendix Two (B) of the Robbins report (+ 22) shows us that of students in main courses in science subjects in Colleges of Education one third are men and two thirds women. If then we look at the O level G.C.E. entries of the Northern Universities Joint Matriculation Board in science subjects we discover that while boys tend to take physics and chemistry and few take biology, many more girls take biology than physics and chemistry put together. The 1966 figures are:

| | BOYS | GIRLS |
|---|---|---|
| Physics | 22434 | 5497 |
| Chemistry | 17517 | 6642 |
| Biology | 9371 | 20870 |
| General Science | 2646 | 2472 |

(* 47, Table 3)

We see that while nearly 80% of boys entries in science at O level are in the physical sciences, these subjects get only 35% of the girls entries, and in Colleges of Education we have twice as many girls as boys. If we ask our girl students why the physical science subjects were not taken, the answers fall into five main categories:

There was no opportunity, since biology was the only science offered.

They are not interesting.

They are too difficult.

They are too mathematical.

They are boys' subjects.

We cannot afford to ignore these opinions, however we may deplore them, in preparing the physical science sections of our course. If we simply adopt the attitude that these arguments are false and our students should know better, we shall fail to engage the attention and sympathy of our students, many of whom have an unfavourable image of the physical sciences.

We must realise, then, that our approach has to be simple and straightforward. Many of our students are frightened by the names and symbols which teaching physicists and chemists take for granted and it will not help in the least if we look down our noses and complain that the sort of physical science which we propose to teach is nothing more than middle school or fifth form work. For some, at first, this is all it is, until we have built up enough confidence to enable them to branch out on their own. Some of our students, of course, are quite knowledgable in the fundamentals of the physical sciences but even so, few will have taken their knowledge out of doors or used it to solve problems of their own construction. Whatever scheme we devise must be flexible enough to provide adequate stimulus for both the uncertain student with a shaky O level basis and for the confident A level student moving forthe first time into biological circles. I do not believe that there is anything basically different in the intellectual make-up of boys and girls which would account for boys being "better" at physics and chemistry, but there is no doubt whatever that there is some factor, emotional or psychological, which causes girls to think that these subjects are more difficult. Nor is it easy to understand why, if girls can be interested in the solution of problems and questions which arise in the biological sciences, they should be so often uninterested in problems in physics or chemistry. One would be tempted to conclude that perhaps the traditional methods of teaching physics and chemistry in girls' schools had failed to interest or instruct the girls, were it not for the evidence that in mixed schools there is the same drift away from the physical sciences by the girls round about the fourth year. If it is true that the boys do not enjoy their physical sciences either, but persevere only in order to obtain necessary qualifications, then indeed our science teaching methods need reappraising. hatever the cause of the neglect of the physical science, particularly by girls, it is certain that in order to arouse interest in it we shall have to "sell" it by making it simple, interesting, and relevant.

In each area of our environmental work we find that, when the problems and investigations have been formulated, various principles, laws, or techniques of the physical sciences are appropriate to the particular situation. We find, however, in each new area of work, that some, perhaps all, of our students are not familiar with these principles and techniques. It is at this point that we must resist the temptation to state the principles, or to give the students enough factual information to carry out the original investigation. If our physical science programme is to be of value it must be based on student investigation, and so the next step is to offer problems and investigations designed simply to bring out the physical science involved. This may need several stages.

Different students bring to the problems different experience and different understanding, and some of them have to continue this backwards search until they reach the very simple and elementary principles upon which the area of work concerned is based. But the value of this movement, from the complex to the simple, is that the student is collecting information or developing techniques or discovering principles which he realises are necessary for the solving of his initial problems. If, on the way down this pyramid of knowledge, he finds new interests and wishes to digress, then by all means let him do so, and we hope this will happen.

One task, then, in the physical sciences is to supply enough basic theory, by investigation, to enable useful questions about environmental situations to be answered. I am confident that once our students have realised that they can find their way through the fields of physics and chemistry in their early researches they will use the methods and information of these subjects to a much wider and deeper extent. We must also remember that we have to persuade our students, as soon as possible, to become involved in a quantitative approach, and as many of them have little confidence in their mathematics we have to be careful not to assume a mathematical agility which they do not possess. A very important part of the work of the physical science tutors is to help with the simple mathematics as applied to data collection, interpretation, and presentation, which occupy much of our course.

We are, however, interested to know whether the physical sciences have a part to play in environmental science, not just as support subjects, but in their own right. Is there a direct, first hand role for physics and chemistry? There has been a tendency fro ecological study to be almost exclusively biological and geographical, and even in recent years we find expressions from authoritative bodies that foster this impression. For instance, the Department of Education and Science, in 1965, in its reprinted pamphlet, "Schools and the Countryside", says:

> "The ideal to strive for is that every piece of field work undertaken should be an original investigation into some problem of interest and importance. It is in this respect that the biological sciences can make a special contribution to science teaching. To pose a fresh problem in the physical sciences is extremely difficult, especially if it is to be capable of solution by the pupils themselves.
> (+ 28,p11).

Recently, however, there has been increasing emphasis on the importance to biological study of physical science considerations, and the publication and popularity of books like "Physics in Botany" by J.A.Richardson (+ 77), "Energy, Life, and Animal Orgaisation" by J.A.Reigel (+ 76) and "Biophysics" by E.J.Casey (+ 14) have shown that when the principles of physics and chemistry are applied to biological problems progress is often speeded up enormously. Not only in the field of biology has the spread of physical science investigation been observed, and the titles, "Physics in Meteorology" by A.C.Best (+ 9), "Physics of the Air" by W.J.Humphries (+ 42) and "Physical Methods in Physiology" by W.T.Catton (+ 15) show this use of applied physics in other areas. It is important to notice that all these books emphasise the need for a more quantitative approach to the work in each of t he fields involved. That this increasing stress on measurement should coincide with a greater use of the physical sciences is not surprising but it also implies a changing attitude of mind from that which considered the biological sciences to be fundamentally descriptive.

However, when we consider the true environmental problem there is no question of whether or not the physical sciences should be involved. It is not possible to conduct any environmental investigation without examining all the factors which concern the organism under discussion, and some of these factors will be physical and chemical factors requiring for their measurement standard techniques of the physical sciences. It has been emphasised again and again by environmentalists that their study is concerned at any instant with a complex of many parts interacting and reacting as a whole, and while it may not be possible actually to measure or to express in numerical terms all the factors involved, it is essential that all should be considered before drawing conclusions. Whether these factors be limiting, compensating, triggering, or merely indecisively fluctuating, they will be changing in space and time, and it is the rates of change, expressed largely in terms of physical parameters which will be of interest to the students. Perhaps one quotation, from Mason and Langenham will suffice to underline the point:

> "We have a concept of environment that is organism-directed, organism-timed, organism-ordered, and organism-spaced." (+ 56).

Many authors see as the first concern of the physical scientist in an environmental situation the exchange of energy. D.M.Gates, of the Bureau of Standards, Boulder, Colorado, says:

"The flow of energy in and out of these environments must in many ways be an extremely critical condition for the existence and propagation of life itself."
(+ 38,p1).

To say that all the work which the physical scientist does in environmental investigation is concerned with energy exchange would be an over-simplification which only begs further questions, but it is surely very helpful to take note of the emphasis placed on the study of energy exchange in the discussions which take place about natural and artificial environments. If we want to find a structural link for our course it might be useful to use energy exchange as the major basis of our work, and since much of what we do in the physical sciences will be done so that students may understand the physical and chemical factors involved in their experimental situations, we can outline the considerations in terms of energy categories which will be involved. In each case it will then be necessary to say what preliminary topics will have to be studied by those who have no previous experience of the particular area. For instance, it is proposed that we begin with solar raditaion as our primary source of energy and this would need a previous study of the nature of wave motion, the natube and properties of light and the electromagnetic spectrum of visible and invisible radiations.

There would follow some work on heat, involving temperature measurement, quantity of heat, heat transfer, and change of state. Other forms of energy would be studied, beginning with kinetic and potential forms and moving to chemical energy, which would bring in chemical reactions, acids and bases, oxidation and reduction, and rates of reaction. Extending the range of study into the biosphere would involve consideration of the chemistry of carbon compounds and some biochemistry, while turning attention to the earth would introduce the chemistry and physics of the earth's minerals and of crystals, and of magnetism. Finally, consideration of electrical energy would require study of the properties of electric charges and electric currents, and of the detection and properties of radioactive materials.

The physical science part of the main course, apart from giving students the information they require, will be used to show them clearly how science theories are built up and how scientific models are made. Much of the work outlined in the previous paragraph could well serve this purpose, but the topic of atomic theory is so important in scientific thinking that it must, in its own right, have a place in our scheme. The proposed stages in the work which the students will do to demonstrate the building up of the theory are these; molecular size; crystals; kinetic theory of gases; colligative properties of liquids; atomic and molecular weights; periodic table; isotopes; chemical laws; electron properties.

Another part of the role of the physical sciences section of the course is to help students to select the data they collect, to construct good experiments which by reasoning or by intuition they believe will answer their questions, to discard the unnecessary, to draw valid conclusions, to decide the best methods of presentation of results, and often to help them to evaluate the worth of their efforts. In order that they may appreciate all the points involved in an investigation which begins with a complicated environmental situation they will need to experience, many times, examples of simple situations involving few variables so that they may see clearly how to arrive at a reasoned conclusion.

The three main contributions of the physical sciences in the main course, to inform, to show scientific theories and models, and to give help in experimentation, have now been indicated. It is well to look at those large sections of traditional physics and chemistry courses which have not been included. Newton's laws of motion and momentum are missing, and with them most of the usual work on force velocity and acceleration. Other missing sections are geometric optics, magnetic and electrical measurements, thermionics and electronics, chemical calculations, chemical analysis, mechanics, sound, friction, and some other smaller sections. There may be good arguments for the inclusion of some of these and no doubt over the years a course of environmental science would show many changes in the light of experience, but at the moment their exclusion does not seem to present problems.

There is another role for the physical sciences apart from that played in the main course. While most students from other main course departments coming into the science department for curriculum courses will best be served by broadly based science education, there will be students in single science subject main courses whose need will be for a balancing curriculum course in physical science. For example, students in main courses in Biological Sciences, or in Rural Science, and those in the earth sciences of Geography and Geology, and others in departments of Environmental Studies which are biologically or geographically based, could well profit by a curriculum course in Physical Science. Students intending to teach in the secondary range of 11 - 16 or or in the Middle School range of 9 - 13 are most likely to benefit from such a course. In a later chapter an example of a suitable curriculum course in Physical Science is outlined and further discussion about it is presented in that chapter.

Having surveyed the field of the course in general and the physical sciences in particular, the next step in this thesis will be to present a complete main course syllabus.

CHAPTER NINE

A MAIN COURSE SYLLABUS

Before the actual syllabus is given, it will be of advantage to outline the main factors, discussed in previous chapters, which have determined the construction of this Main Course syllabus in Environmental Science.

(a) Students should gain, through the course, an awareness of the range of science and an understanding of the capabilities of science.

(b) The course must allow students enough time tp pursue all sections which they study to an intellectually satisfying depth. Different students will need different concentrations in different areas of study, so the course must allow considerable flexibility.

(c) We must accept that, if reasonable depth of study is to be carried out in all the work, this cannot be done over the whole range of such a broad course, that our syllabus must select areas for study, and that much traditional science will have to be ignored.

(d) The areas of science to be included in our syllabus must be closely linked and the selection must be made within the framework of a well defined structure. At all times during the course students should be shown how the different parts are related.

(e) It is almost inevitable that when a syllabus in science is written down it shows its material grouped under headings which seem to indicate a separation into subject disciplines. While this is true of the syllabus given here, there should be no such divisions in the investigations carried out by the students.

(f) The approach to all the work should be through direct investigation wherever possible, leading to problem setting and problem solving by the students themselves.

(g) While the primary object of the course is the personal education in science of the students, the value of the vocational incentive should be exploited by repeated reference to the possible applications of the course work in schools.

(h) Wherever possible the work of each section should be carefully graded in difficulty to allow each student to start at the level appropriate to himself. There should always be some very simple investigations in each section available for those students who have not previously encountered the particular topic.

(i) The syllabus must avoid asking students to repeat work which they have already done and understood. in school. Some students will wish to repeat work they have done because it was not clear to them, and others will wish to approach in a new way topics they have studied by more traditional methods, but those who wish to take up a topic where they left off at school should find this possible in a flexible scheme.

(j) As the course progresses there should be an increasing emphasis on quantitative work and for the weaker students this will require considerable assistance in the simple mathematical processes.

(k) The course should be lively, interesting and purposeful, and should encourage imagination, intuition, wonder and delight in beauty. The student should be made aware of the social consequences of science and should be led to think of the place which man occupies in the progress of science.

The whole Main Course syllabus is given, in complete detail, as an Appendix to this thesis. I now propose to refer to it and to discuss the reasons for choosing what has been chosen and to offer suggestions as to how the different parts should be treated

"Main Course Syllabus. Part One"

The general aimsof this part of the course are to introduce students to the content of the environment as a basis for science study, to encourage them in direct observation, and to stimulate interest and enthusiasm in the solving of problems by direct investigation. All students and staff will work together in this section and public discussion and questions will be encouraged so that the students, most of whom will be the products of formal teaching in one or two separate sciences, can be led gently into the wider fields without being apprehensive. They should be told of the many different backgrounds of the members of the group and as topics crop up those with useful knowledge and experience should be encouraged to offer comments to the others, to lead discussions and suggest profitable lines of enquiry. No attempt should be made to rush through this part of the course. Students should be given plenty of time to look and listen, and to absorb the spirit of curiosity which may not have been a predominant feature in their previous experience of science.

"1. Introduction to an environment.

1.1 General observation. Broad environmental factors. Comparison of different environments."

The course will begin with a general survey of a selected environment, let us say a seashore or a forest or a city wasteland. The perimeter of the area under observation will be defined and the content of the area discussed. The general environmental features such as location, aspect, shelter, vegetation, animal life, weather, geological and geographical features, evidence of man's influence, and others, will be observed and some of the relationships between them considered.

A second, and different, environment will be visited and consideration will be given to those factors which appear to be common to the two areas and to those factors which are different, and to the fact that the same factor may be considerably different in its influence in the two areas.

"1.2 Directed observation of a micro-environment."

Within a general environment previously observed particular microenvironments are selected and the point to be made here is that the environmental factors relevant to a microenvironment are peculiar to itself and changes in them may bear little relationship to overall average changes in the general factors of the larger environment. For example, in a seashore area, a single rock pool may receive particular attention from the student and here, for instance, the brine concentration may be of critical importance to the organisms in the pool whereas, a short distance away at the foot of a cliff its inportance may be much less.

In this work students are helped to learn that observation does not mean simply casually looking at, and the use of all the senses will be sharpened by example and by questioning until they are capable of extracting the maximum amount of information in the minimum time, and are able to record it so that it can be understood later.

"1.3 Isolation of and concentration upon an experimental unit. A single organism or inanimate object as the focus of attention."

It is quite probable that in their previous science work our students may have always begun each topic of study with the problem or investigation already isolated. In physics the lesson which has as its object "To verify Ohm's law" or "To find the ratio of the specific heats of air" is quite common and in biology one often finds a section on dissection which starts with a frog or a dogfish and in which complete instructions are given for the operation. Our students have to be shown that we must fix our attention on a single object if we are to bring our direct general observation to purposeful investigation. So now from the rocky pool environment we select perhaps a crab or a piece of seaweed or the brine itself as the focaus of our attention. This is the simplest form of autecological investigation but here is the beginning of all our work. At first it will be best to suggest to the students that we select small objects as subjects for our study. Later we can move into synecological investigations of populations and communities.

"1.4 Identification of envirohmental factors. Breaking down of generalized influences to specific identifiable and measureable quantities."

Having selected various organisms or objects as examples in different environments, the factors which bear upon these units will be identified in the simplest way. For instance, it is not enough to say that one of the factors affecting the crab in our rocky pool is the weather; we must get the students to clarify this so that the measurable items are separated. The elements of the weather involved can include direct and reflected solar energy in the form of heat, which will depend on the time of year, time of day, aspect and location, solar light, convected heat from the water, conducted heat from the rock, the effect of the wind, the ambient air temperature, and other factors. The other abiotic and biotic factors which affect the crab will also be analysed and simplified until the instantaneous picture of the crab' life at one moment of time is recorded. Some of these factors will be measurable, some not, but all of them have to be considered if the whole picture of the crab's environment is to be obtained. Precision in measuring the correct factor is important. In studying photosynthesis it is necessary to distinguish between the heat and the light factors of the solar radiation and in fact between the colours of the light supplied.

At this stage we shall try to bring the student to realise that the importance of an environmental factor depends entirely upon the organism to which it is applied. The wind to a man may be no more than an uncomfortable way of losing heat, but to a fulmar flying along a cliff face it has a very different significance. Minor changes in intensity and direction of the wind may be quite unobserved by the man but not by the fulmar. The need for precision must be emphasised. Students must see that environmental factors may very considerably over short distances and over short periods of time; for example the humidity in leaf litter at the base of a tree may be very different from that at a point on the bark of a tree a few feet from the ground, and the temperature of the surface of a brick wall may change quite rapidly as the sun is setting.

"2. General environments."

The students having been introduced to the idea of the content of environment and to the method of narrowing down attention until it is focussed on a single unit, the next stage is to stand back and look at the whole range of the work that could be done and to decide on what selection of environments we think are desirable and possible in our particular circumstances. An outline of the environmental factors to be expected in each general situation will help us in our selection.

"2.1 Natural environments. Woodland, freshwater, seashore, chalkland, moorland.
Abiotic factors; radiant energy, temperature, light, ionizing radiations, water, atmosphere, wind, .......... etc .........." ref. Appendix.

These are areas where man has had little or no influence on the ecosystem, and the factors to be studied are physical, geological and biological. They can conveniently classified as abiotic and biotic.

"2.2 Rural environments partly under the control of man.
Abiotic and biotic factors as in 2.1 above.
Factors introduced by man; soil tillage, irrigation, .......... etc .........." ref. Appendix.

The experimental unit in this category of study will be initially a plant or an animal and later a species or a breed. We shall be concerned not only with the outdoor environments of the farmer but also with the controlled environments indoors where intensive farming methods as applied to poultry, pigs and cattle are carried out.

In Chapter Seven I have quoted the conclusion of the McNair Report that it is particularly important that we should not look upon activities in a rural environment as suitable sources of science study only for rural children and teachers. The rural and urban communities have much to offer each other and all students should have the opportunity to see the increasing importance of scientific and technological research to rural life.

"2.3 Urban environment, with plant or animal or inanimate object as the experimental unit. The control by man may be almost complete, as in a greenhouse, partial as in a park, or not at all as on a wasteland or stone wall. Domestic animals and pets."

The environment completely controlled by man, as in a heated greenhouse or aquarium, can serve as an excellent study of varying environmental factors. The value of indoor and outdoor horticultural activities for scientific investigation is considerable and we shall make use of these studies. There is no reason why city and town schools should not include in their scientific investigations not only material which is brought into the classroom but, by using gardens, parks and playing fields, waste ground, walls and pavements, introduce , first hand, biological and physical enquiry to their children. Our students must certainly be made aware of the considerable potential which an urban environment has to offer, and a substantial part of the work which they do should be concerned with looking at plants and animals as they exist in town and city surroundings.

While keeping a large variety of animals in the classroom presents problems, some, like gerbils and tropical fish, are easy to keep. Interest in these animals and fish, as well as in the animal pets which the children have at home will ~~be fostered and used for purposes of investigation.~~

"2.4 The environment of man. Scientific aspects of man in an urban community.
Heat and light from the sun and from domestic supplies.
Clothing. Loss of heat by radiation and evaporation.
Shelter from cold, heat, wind, rain and snow.
.......... etc .........." ref. Appendix.

In many respects the factors influencing man are the same no matter what his environment, the rural man's responses being much the same as the urban man's, but there are factors in the urban life absent from the rural man's experience, so that it is probably more useful to study the urban man and unnecessary to study both. In this area of study we shall concentrate on man and the physical and biological factors which influence him directly. We are not concerned with sociological or psychological aspects of people living in towns, however interesting or profitable it might be to study them. This is a very large area of study and selection within it will obviously be essential.

"3. Basic ecology.

3.1 Content of ecology.....etc.

3.2 Components of the ecosystem.....etc.

3.3 Interaction of organisms.....etc.

~~3.4 Ecological regulation.....etc.~~

3.5 Town ecology.....etc.

3.6 World ecosystems.....etc." ref. Appendix.

It has been pointed out in Chapter Four that unless the students' experience and knowledge is contained in easily understood structure there may be confusion, and so, at this point, having given students practical experience of environment examination, it is now proposed that they should study and discuss, in a more formal way, the fundamentals of ecological practice. This is desirable so that they may understand the many new terms and concepts which they will meet in the reading they will be required to undertake as their work progresses.

The presentation of this summary of ecology should show how it differs from natural history, which is largely content to observe and describe, in that ecology is concerned with observing, describing, collecting and analysing precise data, and drawing conclusions from it.

The problems of the physical sciences and many of the investigations which the students have done in biology in school will have led to precise solutions, easy to repeat and easy to interpret and verify. The problems presented directly by the natural world, whether they be physical or biological in their nature, are more often resolved in terms either of statistical probability or of relationships more casual than precise. We are not looking for an average result taken from a large number of imprecise observations, nor yet are we looking for cut-and-dried "right answers", but some of the appeal of this type of work lies in the scope it gives to flexibility and ingenuity.

"4. The growth of investigations.

The posing of questions and the organising of experimentation and investigation towards the solving of the problems.

The beginning of personal projects."

The next stage of our students' work will be the formulation of problems to investigate, problems which have arisen during the examination of the selected environments. At this stage, however, it is probable that the questions which the students pose will either be simple ones which they can answer fairly easily with a little help, or complex questions which they cannot answer because they have not yet acquired the necessary background information or skill to answer. Later we shall require them to answer some of these complex questions in order that they may have the benefits which result from a piece of concentrated work in a narrow but deep field of investigation. The following are examples of "First stage" simple questions which could be answered in a short time without much specialist knowledge.

Which minerals are magnetic?

Under what conditions is dew formed?

How is humidity measured?

How is a rainbow produced?

Why does the sun look red at sunset?

Why are potholes found in limestone regions?

What causes wind?

What is a cement?

What is steel?

What is a detergent?

How long can food be kept in a refrigerator?

Is the body temperature of man constant?

Why are windows double glazed?

What is a soil horizon?

What is clay?

What is sand?

What is meant by pH?

What is a fertilizer?

What is a normal daily soil temperature range?

How does water reach the top of a tree?

Which trees have winged seeds?

What is an owl pellet and what does it contain?

Why is it hot inside an unheated greenhouse?

Why is a field ploughed?

How is fruit best preserved?

We should encourage the students to find the answers to some of these questions while, at the same time, pointing out that if they are to arrive at questions which will be deeper and more satisfying they will have to learn much more about the basic principles of science and that this will have to be done in a systematic way. So we shall begin the work which is outlined in Part Two of the syllabus and which will be discussed later. This does not mean, however, that we have turned our backs on the selected environments and gone off for good into the laboratory and classroom. Most of the basic work of Part Two will be done by investigation and some of it will be done environmentally, and in addition we shall continue to maintain periodic examination of our environments with increasing knowledge of the principles which govern the phenomena which we observe.

By the end of the first of our three years of study each student should be able to formulate an investigation which will constitute part of his work for the following year. As far as possible the investigation should be proposed by the student though the advice of tutors will be necessary to make sure that its scope and difficulty are appropriate to the student. Each environment will produce its own characteristic questions but some general idea of the nature of the type of questions we might expect is desirable and here it is probably best to categorize them on a subject basis. Some examples are now given of the categories into which the personal project questions might be expected to fall.

### Categories of biological questions from natural environments.

Similarities in living things.

Variety in living things.

Development and growth of plants.

Development and growth of animals.

Distribution and abundance of plants and animals.

Responses and adaptations of animals and plants to changes in physical and chemical environmental factors.

Patterns in animal behaviour.

Interdependence of plants and animals.

Daily and seasonal changes in behavio~~t~~ur of plants and animals.

Changes in populations and communities; succession.

Competition and predation.

Evolution.

Genetics.

### Categories of physical questions from natural environments.

Extraction, classification and history of minerals.

Evidence for and effects of crustal movement.

Landscape changes due to physical factors.

The location, condition and history of fossils.

Relationships between soils and substrate.

Soil characteristics.

Physical effects of stream water.

Chemical properties of sea water.

Fluid flow.

Static water situations.

Physical factors in relation to weather.

Conditions of precipitation.

The content and properties of the atmosphere.

Daily and seasonal changes in environmental factors.

Effects of gravity.

Natural magnetism.

Chemical, physical and biological effects of light.

Changes in temperature and quantity of heat.

Energy exchanges.

Detection and properties of ionizing radiations.

Properties of natural materials.

Categories of questions from environments influenced by man.

Biotic and abiotic content and properties of soils.

Ecological nature of soil.

Nature and properties of fertilizers.

Nature and properties of fungicides and insecticides.

Variations in methods of plant cultivation and animal husbandry.

Ecological relationships in protected cultivation situations.

Factors influencing farm produce.

Response of bees to environmental changes.

Environmental consequences of forestry.

Land utilisation and land spoiling.

The nature and properties of man made materials.

Categories of questions about man.

Nutritional effects of foods.

The purification, supply, and properties of tap water.

Food preservation.

The treatment of milk.

Effects on food of cooking.

The choice of building materials.

Fuels and insulation in connection with domestic heating.

Comparison of types of artificial lighting.

The treatment of refuse and sewage.

Properties of natural and artificial fabrics and clothing.

Man's control of his environment.

Epidemiology.

Pollution of air, land and water.

Radiation hazards.

In addition to the individual investigation which each student will carry out, the group, as a whole or in subgroups, should from time to time throughout the course return to environments previously visited and there carry out group enquiries, particularly those which will provide data which can be processed statistically.

It is seen then that the two parts of the syllabus are not to be considered consecutively but Part Two will begin sometime after Part One.

"5. The collecting of data.

5.1 Sampling, surveying, recording.

5.2 Photography as a valauble tool.

5.3 Instruments; their use and their accuracy. Designing and making instruments.

5.4 Building up an experiment.

In earlier chapters it was emphasised that one of the aims of our course was to get students working in the way that scientists work and one of the areas in which we can put this into practice is in instruction in the way in which data is collected, selected and processed. From the time a problem begins to show itself to the time when the scientist is preparing the conclusions of his investigation he employs a mixture of observation, measurement, inductive and deductive thinking, intuition, hypothesis, and generalisation. The basis of almost all good science lies in exact, precise, qualitative observation. In biological investigation there are the ever present problems of identifying and counting plants and animals, and while this is often necessary, it should be cut down to an absolute minimum and should never be used simply as an exercise, since it can be wasteful of time.

It is not always possible clearly to define the investigation question before beginning, since the question itself may depend upon the initial evidence, but it is desirable that a precise statement of the problem should be arrived at as soon as possible.

Much of the students' previous work in schools may have been done with the materials and the quantities clearly specified and now they are faced with problems of how many samples to take, how to take them and where to take them from; for instance, in problems involving relationships between bedrock and soil, soil sampling may be necessary, or in investigating the eroding effect of the sea on a pier wall, several positions will have to be chosen: both the examples involve decisions of numbers and places which will have to be made. As far as is possible within the limits of time and economy, the students should be left to make the decisions for themselves just as the research scientist has to do. It is not necessary that all students should study all the many systematic and random designs which are used in sampling but rather those appropraite to the tasks embarked upon should be thoroughly understood. Often the recording of places at which observations were made can be done on standard maps, but sometimes details of heights and spacings and irregular shapes and associations require that the students be familiar with simple geometric and trigonometric representation.

It is of considerable advantage if students are able to use cameras for those occasions when it is the best means of recording because of the exceptional or transient nature of the circumstances as in the ice and snow of winter or in remote places or in the laboratory when the setting up of a demonstration or observation is difficult or uncertain of successful repetition. It has been my experience that only when students are required to develop and print their own films do they become enthusiastic and appreciative of the scope of photography in science learning and can acquire enough skill with the camera to be able to take advantage of the unusual situation.

Our students will need to build up, over a period of time, skill in the handling of measurements and will need practice in the use of instruments, mainly relatively inexpensive ones which we can provide for general purposes, thermometers of all kinds, barometers, hygrometers, microscopes, a variety of electric meters, and the like.

In addition they will have to appreciate that some of the instruments which might be desirable for specific purposes may be too expensive, for example, flow meters, continuous recording instruments, colorimetric equipment, and so on; so they will need to devise and make some apparatus for themselves.

A further area in which we can train our students to work as scientists work is in the setting up of experiments as part of investigations. Again we should encourage ~~we should encourage~~ the students, as far as possible, to decide for themselves which experiments they should do and how they should do them in personal investigations they carry out. This is not easy and they will need practice which they can get in their Part Two work which they are doing concurrently with their projects. Perhaps there, in Part Two, the number of occasions when the students can decide what experiments to do will be few, but as often as possible the way in which the experiment is to be done should be left to the student. "Cookery book" science, in which full details, including the conclusions, are given to students before each experiment begins, should have little place in our scheme of work. There are some common faults shown by students when carrying out their own experiments; uncertainty about the nature of the problem; being unrealistic about the problem attempted; employing methods more complicated than necessary; collecting data irrelevant to the problem; failing to modify the experiment in view of information gathered during the early stages. It is by no means easy to show students how to overcome these traps but the experience of them and the ways of overcoming them is a valuable part of their learning.

"6. The handling of data.

6.1 Fundamentals of statistics.

6.2 Presentation of findings.

6.3 Validity of conclusions."

As we have seen in Chapter Two the mathematical ability of many of our students will not be high but nevertheless, as has been emphasised in Chapter Eight, we must make every effort to move the students into quantitative aspects of scientific investigation. On occasions it will be desirable to subject the collected data, particularly that obtained from large "group" observations, to some of the elementary processes of statistics and all students should have some training in this field.

It is not uncommon to find a student presenting a mass of data on temperatures, humidities, chemical composition, and the like, with some graphs of one plotted against another, as the conclusion to an investigation, when in fact no conclusion can be drawn from the data as presented. Other students, having processed their data, present their conclusions in such a fashion that they are not easy to see or appreciate. We would not wish all our students to study deeply the many different tests that can be applied to data nor the many forms of presentation in general use, but some of the simpler tests and a representative selection of the more useful and widely used forms of presentation should be known by the students.

College students, like school pupils, are often apt to draw wrong conclusions from experiments they see or do. This may be due, to some extent, to bad training or example, for it is not uncommon to see in text books, for example, the experiment in which a candle is burned under a jar over water with the unjustified conclusion stated that the experiment shows that the burning candle uses up all the oxygen which is one fifth of the air. We have emphasised the need for creating in the student an appreciation of the way scientists work and part of this is the taking care that conclusions derived from experiments are valid. It is particularly important that potential teachers should be on their guard against taking into the classroom bad habits of slovenly thinking.

"7. Special study of a personal project.

Each student will carry out an original investigation and will present a dissertation upon it."

The personal project will be done partly in periods allowed for on the timetable and partly in the students' own time and will last three terms, preferrably during the students' second year. The choice of the topic will be that of the student though he will be able to call upon whatever advice he needs from a supervising tutor. It is advieable to have a whole year available so that any student involved in a piece of work dependent upon the seasons will havea complete annual cycle.

I have now presented the syllabus for Part One of the Main Course, with some comments on all the sections, and before moving on to Part Two I should like to repeat the fact that the two parts are not to be considered to be consecutive though Part Two will begin after Part One has got under way.

"Main Course Syllabus. Part Two"

As soon as the examination of environments described in Part One of the syllabus has begun to raise questions in the minds of students and they have realised that they need more information and skills, a beginning can be made on Part Two of the syllabus. From time to time, while the work on Part Two continues, further excursions into the areas of work of Part One will be made for two purposes, firstly to prepare the way for each student to select, at the end of the first year, a personal project for special study, and secondly as a recurring reminder to the students that the work of the two parts of the syllabus are closely associated.

Part Two of the syllabus serves several functions.

1. The sections for study have been chosen so that the full breadth of science is shown to the students and they will be asked to consider what elements of investigation and method are common to the various aspects which might be called physical, biological, geological, and so on, and also to consider what variety can be found in interest, in demands, in modes of thinking, in these different disciplines.

2. It is intended to show that there are some great principles of science which pervade almost every corner of the fields of science, for example, the conservation of

energy which will form the starting point for a lot of our work.

3. The interdependence of the different aspects of science will be made clear by showing how the sections of Part Two have been selected to form a logical and integrated structure.

4. Before the students are faced with the problem of mounting an investigation in a natural environment situation, which is probably very complex, Part Two will offer many opportunities to carry out simpler investigations whereby methods of approach and techniques of experimentation and instrumentation may be practised.

5. Part Two will form the basis of a body of scientific knowledge, selective but over a broad front, which can form the background against which discussion about philosophies and principles of science and scientists can be carried out. Without some information, accurate and clearly understood, discussion about the ways of science is impossible. It is not proposed to give a smattering of information about all areas of science but rather to work in some detail in selected areas, leaving the students with a useful science vocabulary and the ability to find information in other areas by using methods of investigation which he has practised.

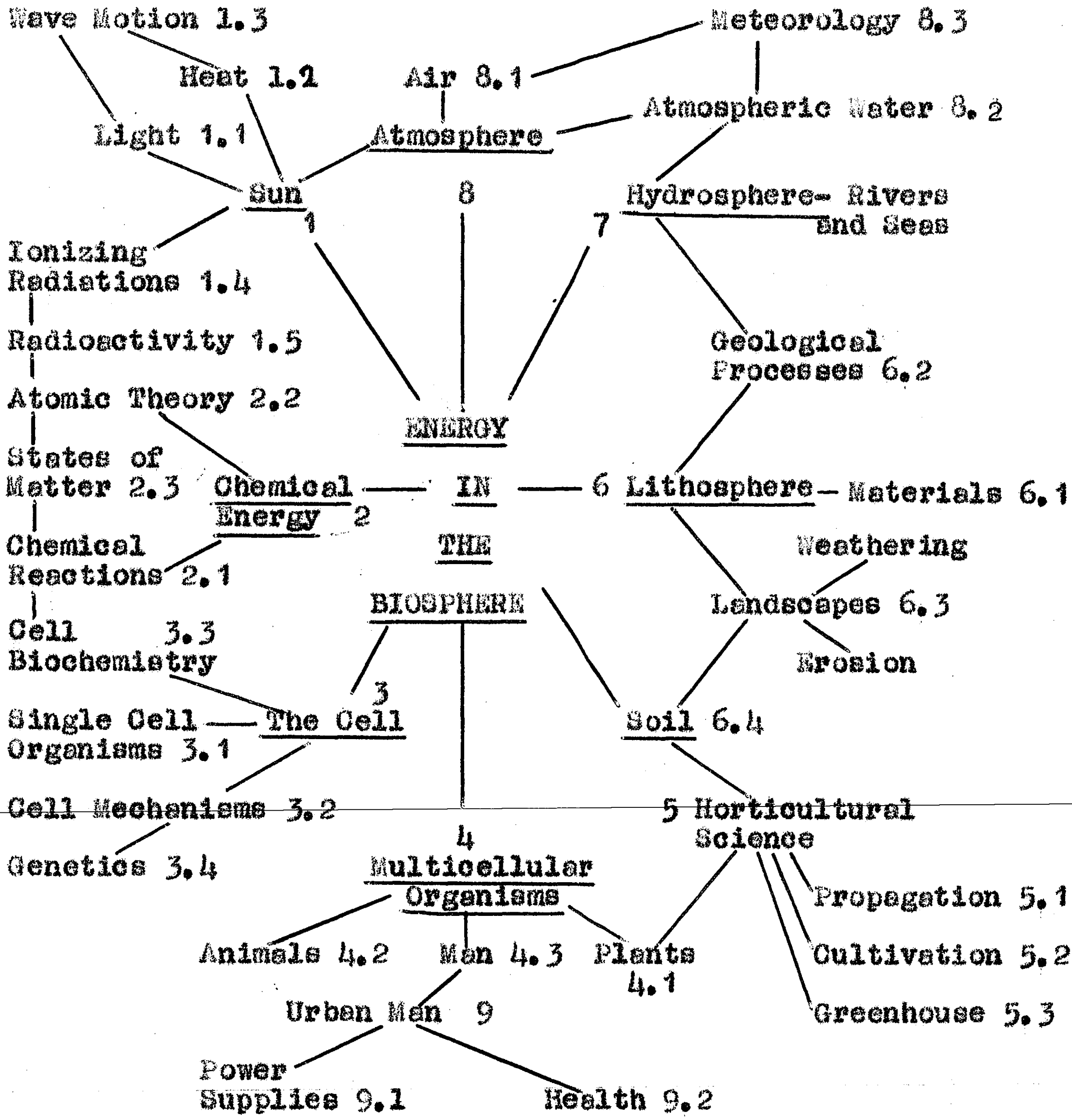
6. Part Two will supply some, though not all, the

background information needed for the successful prosecution of the work of the special studies.

The detailed syllabus for Part Two appears in the Appendix in this thesis and the way in which it was built up is shown on the next page.

It was decided to base Part Two on a study of energy since energy exchange seemed to be a factor to be considered in almost every aspect of our environmental surveys. Two points in particular were made in earlier chapters of this thesis in connection with a science syllabus, one being that as selection is inevitable, a large number of areas of scientific knowledge would have to be missed out and no single area, of itself, being essential to the study of science, the other that only if a topic fitted in naturally to the structure which was being considered should this topic be deemed worthy of study.

The energy changes which we are aware of in our own environments are concerned with solar radiation, atmospheric circulation of winds, water movement in rivers and seas, precipitation, plant and animal activities in the air and on land and in the soil, the chemical changes of gases in the air and in solids and liquids obtained from the earth,




**10. Energy Exchange**

the forces involved in movements within the earth's crust, and energy changes affecting our own bodies. Eight headings were chosen to represent suitable divisions of the total area of work for the course and they were:

The sun
The atmosphere
The hydrosphere
The lithosphere
The soil
Multicellular organisms
The cell
Chemical energy

The steps needed inside each of these areas were then chosen, most of them being automatic choices. It was thought desirable to group them in sections and to number them for convenience. Section 9 on Urban Man and Section 10 on Energy Exchange were added to complete the scheme and the following outline syllabus emerged.

1. The Sun

    1.1 Light.

    1.2 Heat

    1.3 Wave motion

    1.4 Ionizing radiations

1.5 Radioactivity

2. Chemical Energy

2.1 Chemical reactions.

2.2 Atomic theory.

2.3 States of matter.

3. The Cell

3.1 Single cell organism.

3.2 Cell mechanisms.

3.3 Cell biochemistry.

3.4 Genetics.

4. Multicellular Organisms

4.1 Plants.

4.2 Animals.

4.3 Man.

5. Horticultural Science

5.1 Propagation.

5.2 Cultivation.

5.3 Greenhouse.

6. Lithosphere

6.1 Materials of the earth.

6.2 Geological processes.

6.3 Landscapes.

6.4 Soil.

7. Hydrosphere

Rivers and seas.

8. Atmosphere

  8.1 Air.

  8.2 Atmospheric water.

  8.3 Meteorology.

9. Urban Man

  9.1 Power supplies.

  9.2 Health

10. Energy Exchange

It is not, of course, suggested that this is the only syllabus which could have evolved nor yet the best but it is one which satisfies the aims which have been proposed. It is not a comprehensive examination of energy exchange; it is not intended to be. The extent to which a syllabus is allowed to expand depends on how many first step items are to be included and how many second step items are needed, so that the first steps can be properly understood. If, for instance, we specify solar energy as one of our topics then second step items such as heat and light follow automatically and for an understanding of these it is necessary that wave motion be included.

While all sections in the syllabus have arisen naturally, others equally suitable within the structure have been omitted. For instance, energy exchange outside the biosphere has not been included, so there is no section on astronomy and only passing mention of important principles such as Newton's laws of motion and of universal gravitation. To a physical scientist these might appear as distressing omissions but they have been left out because they are not presented to us normally in the course of our environmental investigation and because they represent aspects of science not essential to our needs.

It is assumed that the teaching of Part Two will be undertaken by tutors with special knowledge in particular science disciplines and this is desirable, but it is undesirable that subject barriers be erected at any time. While the numbered sections tend to fall into groups which look like physical science, biological science and earth science this is unintentional and by no means rigid, and no topic is split up and dealt with in different sections. All aspects of air, for instance, are dealt with together and not divided up into physical properties in one section, chemical in another and meteorological in yet another. It is essential that the application of science principles over a wide range of topics should be emphasised. Kinetic energy, for example, should not be studied in terms of a rifle bullet only but its application in atmospheric circulation, ocean tides, animal movements, and the like must be considered. The several tutors will join the students when group or section activities are being carried out and these occasions should serve to maintain the necessary close associations between the specialists. It is not suggested that the sequence given represents a teaching order, rather it is hoped that each tutor will take responsibility for a portion of Part Two of the syllabus and that all tutors involved, probably four or five, would be working with students on their own portions for most of the time given to the course, each tutor being given a share of the time available week by week.. A substantial part of the course will be seen to be outdoor work and when excursions are made all tutors will contribute to the observations, study and investigations involved, each lending his own specialist expertise and personal interest to the communal effort.

In earlier chapters it was repeatedly pointed out that the students on a course such as the one here being proposed will have a very wide variety of science backgrounds and the syllabus must allow for this variety. There are three features of the syllabus which will allow for the kind of flexibility which has been called for.

1. A substantial amount of the students science time in his second year will be engaged in a piece of private investigation which I have called earlier in the chapter a

personal project or special study. The level of difficulty and intensity at which this is pitched will be determined by the student in consultation with a supervising tutor who will ensure that this piece of original work contains all the elements of a rewarding investigation. During the pursuit of this personal project the student will be able to work at a pace which suits him and will be able to concentrate on those areas which he particularly needs to understand in order that his project may progress. He will have this opportunity, at least, of doing one piece of work in depth requiring sustained application, reasoned argument, and formal presentation.

2. It is desirable that a year group of students should move together through the various sections of the ~~s~~ ~~science syllabus which has been drawn up because a completely~~ unstructured approach to the work would be extravagant of time, money and staff potential, and would be very difficult if not impossible to maintain for three years. However, within each section of the syllabus it would not be advisable to have all students doing work at the same level; for some, an average level would be too high and would confuse; for others it would be too low and would bore. It will be seen that the practical work in the secions of Part Two of the syllabus have been drawn up with two levels of student work. One level is judged to be correct for students who have no

more than about Ordinary level experience of the topic in question and the other for those who have had a background beyond Ordinary level. There is no question of "streaming" the students over the course as a whole and a given student will move from Level One in one topic to Level Two in another as he chooses, without any reference being made to his previous G.C.E. experience in the topic. It may be desirable for a tutor to talk to Level Two students in a given topic without having the Level One students present, but generally speaking discussion will be carried out with the whole group, the work of both levels being used as evidence or as example. The Level Two work suggested must not be thought of as being linked to any Advanced Level G.C.E. syllabus. The activities and investigations suggested are regarded as being suitable for students who have reached, in a particular subject, the level of thinking one would expect to find after two years in a Sixth Form. Whether the topics involved are normally in G.C.E. syllabuses at Ordinary or Advanced level or not included at all is immaterial in the context of our syllabus.

3. Even after separating off the Level Two students ther may well be a wide range of understanding, with some students having no experience at all of the subject under discussion. To allow for this the work in Level One in each section has been graded as far as possible so that

the early parts are suitable for an adult of average intelligence who has not come across the subject before, while later parts are suitable for adults of the same intelligence but with some previous experience. Within Level One, then, there will be those students who will start at the beginning of a section and those who will omit some of the early stages because they are confident that they know the answers to the questions involved.

Turning now to the individual sections of the Part Two of the syllabus, it will be seen that just as there was selection of the main headings from a large number of possibilities, and within each main section the subsections were themselves selected, so in the subsections no attempt ~~has been made to cover all the ground which could be~~ included according to the title of the subsection. This approach is adopted so that we should, in our syllabus, satify the arguments advanced in earlier chapters of this thesis that while students should be presented with a picture of the full range of knowledge in any given section, satisfactory depth of study can be acheived only if certain parts are selected for detailed attention and the others ignored.

The heading "CONTENT" in each section shows the topics which will be studied, some by direct investigation by the students using the practical work suggested under the headings, "LEVEL ONE PRACTICAL" and "LEVEL TWO PRACTICAL", others by lecture, discussion, or demonstration by the tutors. The empirical, deductive approach will be adopted wherever possible but there will be many topics in the syllabus which will not lend themselves to direct investigation and it would be unrealistic to try to do so. For these topics the best method may well be to offer by lecture, by hand out, or by reference to text books or library books, the maximum amount of information in the shortest time. An example would be in the section on atomic theory where, apart from student experiment on chemical laws, almost all the work will be done by instruction and discussion.

---

Some comment is now offered on the individual sections of Part Two of the syllabus and as this is given in full detail in the Appendix, and therefore is quite lengthy, the sections will not be requoted in this chapter, where only the numbered headings and subheadings will be used, to help the reader who wishes to refer to the full syllabus.

"1. The Sun.

1.1 Light."

Only those aspects of the study of light which bear upon energy relationships are involved, so there is no mention of geometric optics or of optical instrument theory. All the work in this section is approached by investigation, much of it by comparison of effects, and though the Level Two work is simple it offers fresh work for those with previous experience of the subject.

" 1.2 Heat."

As in 1.1 those parts of the study of heat as a form of energy are included while other aspects such as coefficients of expansion and conductivities are omitted. The work is again entirely experimental and the substances used are natural materials; for example, specific heats are measured for water, soil, and rock, and not for copper rivets. Convection is studied not in a smoke box with two chimneys but in the realistic situation of a greenhouse where its consideration is of practical importance.

"1.3 Wave motion."

Plenty of time should be given to those unfamiliar with wave motion to do individual work with ripple tanks, while those who have done the work before are being engaged in some experimental work of a non-traditional type with sound waves and spectra.

"1.4 Ionizing radiations.
1.5 Radioactivity."

Both these sections will begin with practical investigations which will elicit the information leading to the discussion from a theoretical viewpoint, of atomic nuclei. There will be no division of the group into two levels as the sections are best treated as a single continuous project and because experience of students up to the present has shown that few of them have done practical work in this area of study.

"2. Chemical Energy.
~~2.1 Chemical reactions."~~

Selection of relatively few topics in this area has meant that much of traditional school chemistry has been omitted. There is no mention of systematic analysis, nor is there study of the occurence, preparation, properties, and compounds of a large number of inorganic elements from sodium to manganese. It is felt that much of this work is repetitive and has little vaue as investigational work nor is it seen by students to have great interest or application There would be greater claim, it is felt, for an increased number of topics in organic chemistry, but they would demand more time than was thought justifiable and this part also has been kept small.

"2.2 Atomic theory."
This is necessarily a largely theoretical section and it will almost certainly be necessary to divide the lectures and demonstrations into two groups, some for beginners in this field and later some for all to attend. Little practical work which is directly applicable is available but there are some demonstrations which have been included for the students to see, and this may well be done quickly by having them set up ready for them.

"2.3 States of matter."
This is potentially a large and valuable section and a fair degree of flexibility should be allowed for students to pursue work outside the lines indicated in this syllabus. No great distinction can be made between Level One and Level Two in this section as the field is broad and the scope extensive. Each aspect of the section can be approached by empirical methods and the energy considerations involved should be stressed at each stage. More traditional topics, such as Young's modulus and magnetometry, have been omitted, but where topics are thought to have academic value even though they have apparently no practical value they have been included in the content; examples are

Brownian motion and isomorphism.

"3. The Cell.

3.1 Paramecium; a single cell organism."
It may well be that a number of our students may have spent some time examining single cell organisms under a microscope and they will not need to repeat this by looking at paramecium. For others, however, plenty of time should be given to allow them to study in some detail the structure and activities of this organism since it shows all the basic functionings of animal life.

"3.2 Cell mechanisms."
The standard of technique required for the work in this section, which tries to show chromosomes at work, is much greater than that of the previous section, and it is suggested that sections 3.1 and 3.2 be considered as alternatives as far as the practical work is concerned, with the more experienced students only attempting section 3.2 while the inexperienced are satisfied with section 3.1. Lectures and discussions on both sections could be attended by all students.

"3.3 Cell biochemistry."
This section ranges from very simple tests for sugars to

complicated two way chromatographic separations of proteins. All students should reach the stage of doing some chromatography at least the simplest techniques, and the more experienced can omit the early stages and try their skill at the more sophisticated methods. Generally the Level One students will be satisfied with qualitative work but some of the level Two students should be capable of obtaining some quantitative results.

"3.4 Genetics."

This section offers opportunity for students to carry out practical investigations involving genetics principles, and this is work which can extend over a long period of time. Animal projects are more difficult than plant projects and students will have to select according to their own capabilities and so no attempt has been made to outline, in this part of the syllabus, Levels One and Two.

"4. Multicellular Animals.

4.1 Plants.

This section deals with botanical studies and section 6 later deals with horticultural science, though, of course, there is no sharp division in the subject matter between the two. This section 4.1 is a large one and there is a large selection of practical activities to suit all students. Much of traditional botany has been descriptive and much time has been spent in drawing plant sections, but it is hoped that this course will offer more investigation of the effects of changing factors rather than simple observation of structure. For example, the study of Photosynthesis will include direct measurement of the effects of changes in light, temperature and carbon dioxide concentration rather than just microscopic observation and chemical testing for presence and absence of starch and sugar.

"4.2 Animals.

There is only one section on animals, unlike the work on plants which has been divided into botanical and horticultural sections. If animals are to be studied alive, and it is very much better science if they are, then the practice of animal husbandry will have to be linked directly with the zoological study and no useful purpose would be served in separating them. The work is very varied and provides all students with ample scope for their own interests so that division into Levels One and Two is not necessary. There is no ecological study in this section since it has already been discussed in Part One of the syllabus.

"4.3 Man

This is not a traditional section on human biology. It is concerned with looking at man as an organism subject to a variety of environmental factors, some of which have been selected for study with a view to emphasising the energy relationships between man and his environment, and the physical factors which influence him. Practical work is concerned with investigations which can be carried out directly by man on himself and which are largely related to his senses.

"5. Horticultural Science."

Horticultural science offers a large and valuable field for investigation provided the correct approach is adopted. Some skills will have to be taught before the practical work can be done but the minimum amount of time should be spent on them. The object is not to grow bigger and better flowers and vegetables but to use plants as scientific material, for which they are admirably suited. It will be noticed that in the sections on propagation and cultivation all the work suggested is concerned with problem solving. In the third section the greenhouse is studied as an almost ideal example of a controlled ecosystem where all the factors can be changed and the results of the changes examined. This is environmental science on the small scale but all the principles are here for investigation.

"6. Lithosphere.

6.1 Materials."

The section on materials of the earth has its main link with chemical energy though it is not easy to show this on the flow diagram of the whole course. The physical and chemical tests on common minerals will call upon the previous experience of some of the students though few of them will have done a formal geology course, and the work on rocks will probably be new to most of them.

"6.2 Geological processes."

The work of this section will be one of the few on the course where lecture and discussion will precede practical work, since travel and field work will be involved and since few of the students will have a great deal of geological background. To save time in the field it is best if maps and photographs are used first to give clear ideas of what the students will be looking for first hand when they move out on their expeditions. This is one of the sections of the course where one might expect some sophisticated group work to be done, ending perhaps with a presentation employing a variety of visual aids.

"6.3 Landscapes."

The study of the development of landscapes by weathering and erosion will be determined largely by the local circumstances in the areas available to the college. The The amount and nature of the preparatory laboratory work considered desirable will depend on the students' backgrounds and some provision has been made in the two levels of work, but once in the field all students will work together in observing, recording, collecting, photographing, and discussing. Again a combined presentation would give an opportunity for group participation and for experimental displays.

"6.4 Soils."

Work in soils must be organised so that it is concerned with investigations and problems and not just carrying out routine physical and chemical tests. Some time will have to be given to those unfamiliar with this work, since to gain full advantage of the information which the soil can give, care in observation is essential. There are, however, plenty of complex questions for the more knowledgable to tackle while the others are engaged with basic principles.

"7. Hydrosphere. Rivers and Seas."

While some consideration must be given to the hydrosphere to satisfy our need to include in our broad picture all the aspects of science, only a short time should be spent here, since the amount of profitable investigation which can be done at student level is small and it is not a subject which lends itself to study by our environmental approach. The subjects of oceanography and climatology have been omitted and the emphasis has once again been laid on energy considerations.

"8. Atmosphere.

8.1 Air.

8.2 Water in the atmosphere.

8.3 Weather."

The section on air is an important one from the point of view of energy exchange on the large scale in the form of atmospheric circulation, but since it offers little scope for real direct investigation use will have to be made of diagrams, models, and pictures to make discussion profitable and understandable in this section. The section on water in the atmosphere, on the other hand, does offer some useful measurement and some calculation in areas of saturated and unsaturated vapours and relative humidity. The most profitable area for instrumentation, however, lies in the section on meteorology where a large variety of mechanical and electrical measuring instruments should be used in the collecting and processing of physical information. It is quite common for student groups to set up weather ~~st~~

stations but this course does not propose to do so, since it is thought that much of this labour is profitless repetition. All students should use all the recording instruments but discussion of weather maps and prophesies of future weather should be based on published meteorological office information in order that student time should be conserved.

"9. Urban Man.

9.1 Power supplies.

9.2 Health."

In Part One Section 2.4 the ecology of man was examined. In Part Two Section 4.3 man was examined as a single biological organism in a physical environment. In this section 9 we wish to consider him as an organism in the particular environment of the town. Discussion will at first be concerned with all the factors, heat, light, shelter, food, air, disease, and so on which affect urban man. From these many factors two are chosen for particular study, one being the supply of power in the forms of electricity, coal, coke, coal gas, natural gas and oil, and the other, urban man's health involving aspects of water supply, nutrition, pollution and hygiene. The approach in this section is typical of that suggested for all parts of the course, first the whole range of the subject is mapped out and then particular topics are selected for detailed consideration and all the rest are ignored.

"10. Energy Exchange."

Finally the section on energy exchange gathers together many of the ideas which have been developed during the course and tries to show the relationships between the different forms of energy, to trace some natural cycles of energy and to complete any linkages which are still incomplete in the structure of the course.

It will be appreciated that students will not be able, in the time available, to do all the work given in the course syllabus, but it has been made too big intentionally, so that tutors and students will be able to select from ~~the material of the syllabus since it is not expected that~~ all students on any one course will do the same work, and certainly different colleges will wish to make different selections.

CHAPTER TEN

# CURRICULUM COURSES

Most of the College of Education students who come to science departments for a curriculum course will have had very little science background. Hardly any will have done any science beyond Ordinary G.C.E. level and many of them will have studied only one science, often biology, in the middle school years. The typical curriculum course will last for one year and will occupy one session of two or three hours each week. In this relatively short time available the course must satisfy several different requirements.

The course should allay the various fears which many students will have about the possibility of being asked to teach science, fear of ignorance of the facts which they feel they ought to know about science if they are to teach it, fear of the pressure which they think technology applies to those who come in contact with it, fear of the scepticism and disrespect for authority which they believe to be the consequences of studying science, and fear about the difficulties of handling equipment they consider to be complex and perhaps dangerous.

The course should also destroy some of the myths which have grown up about scientists, that they are unemotional, unappreciative of beauty and unaffected by ugliness, that they lack imagination and are devoid of creative expression, and that they have minds which are in some way different from those of other people.

The course should show the cultural value of science, mainly by showing what science can do and what its range is, but also by giving the students the opportunity of being scientists themselves. Anyone doing a scientific investigation is a scientist, and no matter what level of science is involved, those who are involved will be thinking as scientists think, and this is perhaps the best way to show the value of science to man's thinking.

The course should satisfy, as far as it can, the vocational needs of the students as potential science teachers. I have assumed that the majority of students coming to science curriculum courses will be those intending to teach in primary schools or in the lower year groups of secondary schools. Science teachers for older pupils will be graduate or Wing College specialists or products of main course science departments. The vocational needs will include the coverage of some simple basic principles, straightforward information in unfamilier areas such as the keeping of animals in the classroom, practice in the mounting and carrying forward of investigations in science to fruitful conclusions, experience in experimentation, instrumentation and the use of common materials, and some knowledge of the recent history of the discussion of science teaching methods. Students should be aware of the changes which have been advocated in recent years and of some of the reasons which have been advanced in support of the proposals.

Finally, the course should provide the students with a comprehensive guide to the resources available to help the science teacher, the books, films, apparatus, materials, field centres, commercial enterprises, and public bodies, which he will be able to use or call upon for assistance. There are many ways in which curriculum courses could be constructed to satisfy these needs. I offer outlines of two possible courses. One is a course in Primary School Science for students from main courses other than science and the other is a course in Physical Science for those intending to teach in the Upper Juniors and Lower Secondary, in some areas called the Middle School, age range, whose main course is one of the biological, earth, or rural sciences or an Environmental Studies course which does not include Physical Science study.

## CURRICULUM COURSE ONE

## PRIMARY SCHOOL SCIENCE

### A. Work at Student Level.

1. Directed observation working indoors.

This section, which introduces the course, is intended to show the students that all scientific enquiry begins with carefull observation, that the power of observation needs to be cultivated, and that even the most commonplace materials can be the source of interesting and purposeful investigation.

#### 1.1 Soil.

A handful of freshly dug soil is uded as the first example. At first, using only the five senses, unaided, the soil is examined as carefully as possible and the different constituents, living and dead, are separated. Attempts are made to identify and classify what has been found. The need for help in observation becomes obvious and hand lenses, binocular microscopes and monocular microscopes are introduced.

#### 1.2 Pond water.

A sample of pond water provides the second material for observation and some extension of the work done on soil is required. Techniques of catching and observing the fast moving water creatures are developed and the use of elementary keys is suggested.

### 1.3 White powders.

Starch, baking powder, plaster of Paris, sugar, and salt, are the five powders offered as the third sample for investigation. After preliminary examination by sight, touch, smell and taste, it becomes obvious that some form of experimentation will be needed if the examination of the powders is to reach a satisfactory conclusion.

## 2. The need for experiments.

### 2.1 The soil.

As an example of what can be done as a first step in the setting up of experiments the soil is dried, some of it in air and some in an oven, the two samples being compared. Particle size is investigated by shaking up the soil in water in a long plastic tube and allowing the particles to settle. A further sample of the soil is heated strongly in a fume cupboard until there is no further change and the substance remaining compared with the original soil.

### 2.2 The powders.

Three simple tests are carried out on the powders of section 1.3 to show how chemical tests can help identification. All the powders are (a) heated, (b) tested with iodine, (c) tested with vinegar.

3. Directed observation outdoors.

3.1 The potential of the immediate environment of the college is examined from the point of view of scientific work, and activities such as nature trails, plant collecting, bird tables, cloud identification, and stream features, are discussed. The difficulties involved in attempting outdoor work with children are considered. Too much time should not be spent in identifying collected wild flowers form flora. This practice has only limited educational value.

3.2 Two particular activities in connection with outdoor work have been selected as being typical, and the first of these concerns trees. Apart from observation of the shape of the trees and their bark, branches, twigs, leaves, flowers and fruits, tree study can involve elementary survey in the preparation of plans, and simple mathematics in the determination of heights. This is also a suitable occasion to introduce the ideas of ecology as applied to a single tree, or to a shelter belt or perhaps to a woodland.

3.3 Birds.

The second selected study for the outdoors is that of birds. Identification of the common species is a useful beginning but too much time should not be spent looking for rare specimens. Observation of the behaviour of a particular species or even of a particular bird can follow, with additional work on the relationship between structure and function of the different parts of different species of birds. If time permits bird tables and bird boxes can be constructed.

4. Methods of recording and presentation.

Students should engage in a large variety of recording methods used in primary schools and should consider how the presentation of science material can best be made in the classroom. These are some of the topics involved:

Leaf pressing.

Leaf prints with paints and crayons.

Leaf prints with blue print paper.

Leaf and bark rubbings.

Leaf and bark plaster casts.

Animal track plaster casts.

Photography.

Wall displays.

Nature table.

Discovery table.

Weather charts.

5. Measurement: Number.

Students should be aware of the desirability of introducung measurement into science study as early as possible. The first measurement subject chosen is that of counting or estimatimg large numbers of objects. One way of introducing this activity is with jars of different sizes containing objects such as panel pins, nails, peas, beans, and rice grains. There are many ways in which the number of objects in each jar can be estimated. The following six are suggested:

Individual counting.

Counting the individual number in one sample of the whole and estimating the number of samples in the whole.

Forming a regular figure and estimating by area.

Successive halving.

Weighing a counted sample and weighing the whole.

By ratio, comparing sizes of individuals of known and unknown numbers.

6. Measurement: Length, Area and Volume.

Students should be shown that a given investigation involving measurement requires a particular degree of accuracy and to give insufficient or too much accuracy is either unsatisfactory or wasteful of time. Students should also see that all measurements are approximations and they should always be aware of the degree of accuracy inherent in the measuring instrument.

Exercises in guessing and measuring distances with rules of different accuracies are encouraged. The results of a group of students should be examined and the meaning and value of an average discussed. Indirect measurements such as the thickness of a sheet of paper should be made. Area measurement of regular figures can be calculated and of irregular figures can be estimated with squared paper or by weighing using cut out figures. Volumes of regular shapes can be obtained by calculation and of irregular solids by displacement of a liquid in which they are insoluble.

7. Measurement: Angles.

Angles in a horizontal plane are studied in relation to magnetic north with a bearing compass, and the meaning of a magnetic bearing made clear. Comparison of true north with magnetic north can be made using the shadow of a pole. Angles in a vertical plane are measured with a home made clinometer and vertical heights obtained from scale drawings.

8. Weighing.

Various types of home made equal arm balances are shown to the students and their values in particular circumstances discussed; some better for liquids, some for heavy articles, and so on. Unequal arm balances are made, including the drinking straw "microbalance", for which suitable "weights" are discovered, and the lever balance. The general idea of balancing is pursued and the idea of centre of gravity is developed. The influence of the shape and position of the pivot on a see-saw is investigated. Irregular cardboard cutouts are suspended and their balance points guessed and checked. The second method of weighing by spring balance is shown in both extension and compression ways.

9. Timing.

A wide variety of the methods used to tell the time is shown, from water clock to those depending on the frequency of the electric mains. The pendulum is studied as a particular example of a time telling device. The relationship between the period of a pendulum and its length is used to draw attention to the use use of graphs.

10. Related measurements.

Students conduct a series of experiments taking pairs of measurements which are related to one another in a variety of ways. They are then shown how the relationships can be displayed graphically. The object of this section is to give the students, whose experience in quantitaive work will generally be limited, the chance of doing a number of simple experiments which require numerical values to be measured and processed. In all cases the simplest possible apparatus is used.

10.1 Add weights to a tin can suspended on linked rubber bands. Plot weights/length of bands.

10.2 Heat water gently in a tin can. Plot temperature/time.

10.3 Allow hot water to cool in a tin can. Plot temperature/time.

10.4 Add weights in tin can suspended on linked rubber bands and allow to oscillate vertically. Plot Period/load.

10.5 Hang a heavy bar on a vertical wire and oscillate as a torsion pendulum. Plot period/length.

10.6 Allow metre rule with holes in to oscillate as a compound pendulum about different holes. Plot period/position of pivot.

10.7 Allow marble to run down a slope. Plot time/inclination.

10.8 Allow water to run out of a burette. Plot time/burette reading.

B. Science for Primary School Children

11. Films.

"Into Tomorrow." Nuffield Foundation.

"Science in a City Primary School." J.Bradshaw.

"Science in a Country Primary School. J.Bradshaw.

The above films are shown to give students an overall picture of the standard of work which might be aimed at. It is not suggested that the work shown in the films should be copied.

12. New tendencies in primary school science.

Students are given a lecture which summarizes the suggestions made in recent years for changes in method and content of primary school science. A bibliography of official publications will be given to the students. Discussion on the films and publications will be encouraged.

13. Group investigation by the students.

Each group of students will plan an investigation, at their own level, but carried out within the pattern of primary school science. Having decided on the main topic possible flow diagrams will be prepared and each student will carry out a personal investigation. After two or three sessions of private work students report back to the group on their findings and a display or presentation is mounted. This is considered to be one of the most important parts of the course and represents the focal point for all the work done up to this point.

14. Starting points.

Many students express difficulty in knowing how to start off investigations with primary school children. Any purposeful activity can act as a starting point for investigational science. Some very simple activities are suggested to the students who will carry out these activities so that they can see exactly what interest there could be for the children in them, and to see the difficulties they might present.

Dropping coloured inks into water in vessels of different sizes and shapes.

Dropping coloured inks and water on to blotting paper, paper towels and filter papers.

Looking at coloured chalk marks on black or on white paper through coloured filters.

Floating plastic sticks on water.

Adding tiny drops of various oils, methylated spirit, detergents, and camphor, to a water surface.

Making designs with a sand pendulum.

Writing with invisible ink.

Watching air bubbles, marbles, sand, and coloured inks, moving in inverted plastic tubes.

Adding coloured ice to cooking oil.

Adding washers, nut, and bolts, to a tin can on elastic bands.

Finding symmetrical words by looking at them through a mirror.

Stretching fuse wire till it breaks and examining it with a lens.

Forming patterns of glass beads on a tray.

Play with magnets.

Mixing ice and salt to get them as cold as possible.

Making a button flywheel.

Making soap bubbles and soap films with wire frames.

Making patterns with a bubble raft.

Launching a detergent bottle rocket.

15. "Which" investigations.

A form of investigation popular with children and usually relatively easy to prepare is one which follows the pattern of "Which washing powder washes whitest?". The value of such an exercise lies in the emphasis placed on the need for controls and on the validity of conclusions. From a wide range of possibilities the following are examples:

The fastness of dyes.

The speed of setting of adhesives.

The strength of adhesives.

The cleaning power of detergents.

The effectiveness of stain removers.

The surface given by polishes.

The gloss of varnish paints.

The power of household disinfectants.

16. Change.

Some investigation in science, because of their nature, have to be extended over a period of time. Children should be involved in carrying out some observation of phenomena which are gradually changing with time. These observations of change should also be made by the students. The following are some examples:

The setting of jellies of different consistencies.

The growth of moulds on common foods.

The germination of seeds in moist foam rubber between glass plates.

The corrosion of metals.

The collecting of dirt from the air on a clean cloth.

The growth of crystals in a "chemical garden".

The growth of a bulb in spring.

The decay of a wooden post out in the open.

The life cycle of a fly.

17. Working with children.

Before the course is finished, and when students have gained some confidence, every effort should be made to let each student work with a small group of children while they carry out an investigation which, if possible, the children have thought up themselves, with the guidance of the student. Discussion of the difficulties and success during these investigations is of great value and satisfaction to students.

C. Information and Practice.

18. Plants in schools.

In the past Nature Study in schools has often consisted of the collecting and classifying of flowers. However, plants in schools can be used with much greater effect if they become the means of answering questions and the basis of investigations. Students should work with plants and learn their potential for scientific enquiry, even with young children.

18.1 Germinating seeds.

Investigations are carried out on germinating seeds under different conditions of temperature, humidity, light, and air, and percentage germination is calculated.

18.2 Growing plants.

The best growing conditions for a selection of different plants, the effects of varying the nutrients supplied, the effects of pricking out, thinning and pruning are among the problems which can be investigated.

18.3 Propagation.

The various methods of propagation, by seed, root stem and leaf cuttings, division and the others, are practised by students and the relative effectiveness for particular species compared. The effect of stimulating hormones can also be examined.

18.4 Pests.

For older children, the control of pests can form a useful study. This should be offere as an option to students keen to follow up this type of work.

19. Animals in schools.

Problems of housing, feeding, and cleaning animals, and particularly of housing during weekends and holidays, have resulted in many primary schools being without live animals to study. Other schools have been satisfied with keeping animals in cages or fishes in aquaria simply for observation, which offers considerable if often short lived interest to children but is somethigg of a waste of valuable scientific potential. If investigations on feeding and growth of animals, and variation of behaviour in changing circumstances are carried out, then the animals become much more valuable.

In this course only a small selection of animals can be dealt with in the time available and the following three have been selected.

19.1 Tropical fresh water fish.

With the electric water heater, thermostat, air pump, and light bulb, necessary for the tropical aquarium, conditions can be changed to suit different fish. The choice of water plants, the nature of the ground base, the best food, and the types of fish best suited to different conditions can be studied. Observation of life cycles of different species offers a survey which will engage the interest of children over an extended period of time.

19.2 Gerbils.

One of the easiest of mammals to keep in schools is the Mongolian gerbil. He is odourless, friendly, and curious, and can be left in school over the weekend. He offers scope for all the usual investigations carried out with mammals, on growth and nutrition, and on habits, and students should learn to handle and feed them and to maintain the quarters in hygienic conditions.

19.3 Stick insects.

Insects can be housed in very small spaces in classrooms and are easily fed. Stick insects move slowly and observations and measurements are therefore simplified. Furthermore they offer an opportunity to introduce something unusual into the classroom, but the novelty will wear off quickly unless they are made the subject of purposeful enquiry.

20. Basic principles. Electricity.

While it is impossible in a curriculum course of this type to give an "instant science" course, an attempt will be made to help students to understand some basic principles. Sections 20 - 23 deal with four main areas, the first of which is Electricity, and in each section some indication is given of those topics to which the students' practical work could be directed.

Dry batteries and bulbs. 1.5, 3.0, 4.5 volts.

Useful battery clips and connections.

Making bulb holders.

Bulbs and batteries in series and parallel.

Conductors and insulators of electricity.

Conduction of electricity through solutions.

Effects of a current; heating, magnetic, chemical.

Making primary cells, voltaic and leclanche.

The cycle generator.

21. Basic principles. Light and colour.

Light and shadows. Moving shadows from the sun.
Pinhole camera.

Refraction. Liquids in bottles. Prisms.

Lenses. Magnifying glasses. Real images.

Coloured, transparent, and opaque, objects.

Colour mixing. Pigments and chalks. Dyes. Whirling discs, coloured lights.

Spectra from prisms, gratings, and mirrors in water.

22. Basic principles. Air.

22.1 The reality of air.

Emptying and filling containers with air under water. Finding air in soil, tap water, a brick. Paper aeroplanes and boomerangs. Air resistance with revolving vanes and parachutes.

22.2 Compressibility of air.

Cycle pump. Air in jars under water.

22.3 Air has weight.

Pumping up a petrol can or plastic container and weighing.

22.4 Air has pressure.

Droppers and suction caps. Collapsing detergent bottles.

22.5 Composition of air.

The shell game; guessing time of burning candle.

Rusting of steel wool in moist air.

Lung capacity.

Carbon dioxide as a product of breathing and burning.

23. Basic principles. Water.

23.1 Buoyancy. Floating and sinking. Simple hydrometers.

23.2 Solubility. Cold and hot water. Solutions, suspensions, gels. Water purification, decanting, filtering, distilling, boiling. Hardness of water, soaps and detergents.

23.3 Frozen water. Melting ice cubes with different warm solids. Force of expansion.

23.4 Surface properties: oil films, camphor boats, shapes of drops, soap bubbles and films, water absorption and evaporation.

23.5 Water pressure: cans, U tubes.

24. Working with materials.

A primary school teacher will usually be required to make all the models and demonstration equipment needed. This course will offer the opportunity for all students to work in glass, wood, perspex, tin plate, hardboard, pegboard, balsa wood, polythene sheeting, and a variety of card and paper. Pieces of useful equipment, such as simple balances, weather vanes, spatulas, and the like will be made by the students.

25. Resources for teachers.

The course will offer to students collected information on the following source materials:

Books and wall charts.

Films and film strips.

Gramophone records and tape recordings.

Apparatus and equipment.

Materials.

Commercial firms, organisations, public bodies.

## CURRICULUM COURSE TWO

## PHYSICAL SCIENCE FOR THE 9 - 13 AGE RANGE

This is an example of a curriculum course provided for students who expect to teach children of the age range 9 - 13 years, which for the sake of brevity I shall call the "middle years". In most schools which have had children in this age range, the lower forms of modern, grammar, and comprehensive schools, with children of 11 -.13, and more recently in Middle schools, the science teacher will often be expected to be able to teach aspects of biology, chemistry, and physics, or some form of general science. We have seen in Chapter Two of this thesis that very few students in Colleges of Education take Physical Science as part of their main course, so there is obviously great need for curriculum courses in Physical Science for this age range. This course has been designed for students in main courses of Biology, Geography, Rural Science, and Environmental Studies where physical science is not included. A Physical Science curriculum course for main course Mathematics students is certainly needed but the course we are now considering would not be very suitable because the mathematical content is pitched at a level not appropriate for the mathematicians.

It is a curriculum course in Physical Science with some emphasis on the associated Mathematics since we know that students in main course of Biological and Earth Sciences are generally poorly equipped in Mathematics. It has been specifically directed towards the middle years range because it is in this range that the change from the unstructured Primary School science to the more formal organisation towards separate subject disciplines will take place and we must equip our students, as far as we can, for this important phase of future science teaching.

This course would require half a day, about three hours, for most of one year, that is about 28 weeks, allowing for teaching practice time.

There are three main divisions of the course:

1. Examination, measurement and information.

The aims of this section are to draw the attention of students to phenomena in the surrounding environment where he can see examples of the application of physical science principles and where he can acquire some factual knowledge of these principles. He will be led on from simple observation and examination to see the need for experimentation and will be asked to set up tests and experiments and to say what conclusions he has been able to arrive at.

2. The development of theories. Molecules and atoms. In this section the student will be asked to emphasise the quantitative aspect of physical scienceand to direct his attention to abstract ideas, to theories and models which have been developed during the advancement of science.

3. Changing patterns of science teaching. The students and tutor will discuss the various changes proposed for the teaching of science at all school levels in recent years. It is necessary that in a course directe d to the middle years range the students should know what to expect from the pupils on arrival and the kind of science teaching they will be going to when they move on.

The course will retain as far as is possible the environmental associations previously discussed in this thesis but most of the work will be done in laboratories or close to the college to economise on time. The short time available will also mean that there will have to be concentration on a small number of selected topics and breadth of study will have to be sacrificed, to some extent, in favour of complete understanding of the selected physical principles and the practice in manipulation of the calculations. It is, however, essentially a practical course, in that discussion will be about information collected or observations made by the students.

The mathematical content of the course will include consideration of the following:

Verniers and micrometers.

Solving of linear and quadratic equations.

Logarithms.

Trigonometrical ratios.

Practice in graphical methods for linear, quadratic, hyperbolic, and exponential, functions.

Degree of accuracy and uncertainty in results derived from measurement.

Two dimensional vectors.

Elementary probability and statistics.

The mathematical topics will be dealt with when the need for them arises in order to be able to understand principles in the physical sciences studied. In other words, the mathematics will be taught as a necessary tool in the learning of science and not as isolated academic activities.

It must be emphasised that this is a curriculum course and all the work done will be discussed in terms of its relevance in the classroom.

## A. EXAMINATION, MEASUREMENT, AND INFORMATION.

### 1. Materials I. COMMENT

A large number of different common materials is provided and students begin by examining them, identifying and naming them, and trying a simple classification. They are led to realise that while their own senses are satisfactory up to a point, the need arises for more subtle distinctions and ideas of identification by melting point , solubility, and conductivity are discussed and practised. The need to measure length, mass, number, area, volume, and density, and the like, arises and all these measurements are carried out with discussion of accuracy and significan figures.

---

SYLLABUS

Sample materials: zinc, aluminium, lead, iron, copper, oak beech, wool, cotton, silk, brown paper, cardboard, blotting paper, polythene, mica, perspex, glass, brick, marble, sandstone, granite, coal, peat, graphite, vaseline, beeswax, paraffin wax, salt, sugar, washing soda, alum, naphthalene, camphor, cooking oil, petril, paraffin, methylated spirit, vinegar, water, glue.

Identify and classify the above materials using first only the senses. Decide which additional tests would be suitable for the identification of those materials which are alike in properties. Use melting point to identify naphthalene and boiling point to identify colourless ethanol.

Introduce ideas of density and specific gravity. This requires measurement of mass and volume, which in turn introduces measurement of length and area.

Measurement of length. Estimation. Degree of accuracy. Significant figures. Verniers, micrometers.

Indirect measurement of length. Scale maps, shadows, pin hole camera. Heights of buildings and trees. Geometrical and trigonometrical measurements. Measurement of angles. Similar triangles. Bearings. Elementary survey. Ratio and proportion.

Measurement of mass. Equal and unequal arm balances. Sensitivity. Straw balance. The lever law. Spring balances.

Measurement of area and volume in metric units. Rectangles, circles, triangles, Surface areas. Volumes of regular solids. Areas and volumes of leaves and trees. Volume by displacement. Addition of volumes, salt and water, cooking oil and water, methylated spirit and water.

Measurement of density by mass and volume. Specific gravity by Archimedes method. Simple hydrometer. Density of air by direct weighing. Density changes, water, snow, ice, steam, water vapour.

2. Materials II.

COMMENT

Beginning again with a different collection of common materials the students' attention is directed towards the use of chemical methods for identification and classification. Investigations include simple analysis and testing of soil, acidity and alkalinity, distillation of crude oil, extraction of metals from ores, reactivity of metals, the properties of carbon, and the constituents of sea water. This section contains few references to mathematical operations.

SYLLABUS

Sample materials: crude oil, petrol, paraffin, lubricating oil, calor gas, malachite, copper pyrites, haematite, coal, coke, tar, bauxite, galena, limestone, chalk, sandstone, pebbles, sand, loam, clay, fossils.

Use the above substances to introduce students to some simple chemical techniques for identification and classification. The following are examples:

Soils; air, water, humus, content, size of particles, flocculation, pH values.

Oils. Separation of components of crude oil by distillation.

Metals. Extraction of lead from lead carbonate, of sopper from copper pyrites. Reactivity table of metals selected from sample materials I. Place of carbon in the table.

Investigate metallic ores using flame tests, carbonate test, magnesium test and sulphate test.

Chemicals from the sea. Evaporation. Identify calcium, sodium, potassium, magnesium, chlroide, brómide, iodide in sea water. Electrolysis of sea water. Obtain iodine from laminaria seaweed.

3. Forces and Movement.

COMMENT

Examples of naturally occuring forces, wind and moving water, for instance, are the starting points for investigations into forces. The measurement of forces by the stretching of a spring and by the acceleration produced in known masses leads to questions of elasticity, and of the measurement of time, speed, and later acceleration. Graphs of different kinds are examined to help with the processing of data. The newton and the joule are discussed and the section ends with experiments on hydrostatics and air pressure.

SYLLABUS

Fobces in contact: wind, moving water, pushes and pulls; forces at a distance, gravity, magnetism, electbric forces.

Measurement of force by a spring. Elastic properties of wires and springs. Hooke's law and its limits. Linear graphs, slope of a graph.

Measurement of time. Pendulums. H yperbolic graphs. Use of ticker tape machine for measuring time intervals.

Measurement of velocity. Unifrom velocity of a friction compensated trolley. Terminal velocity of a glass bead falling through a liquid. Velocity/time graphs, distance travelled as area under the graph.

Uniform acceleration, ticker tape histogram from accelerating trolley. Acceleration due to gravity. Effect of shape, size, and surface area.

The newton.

The joule as a unit of energy.

Pressure. Water U-tubes. Mercury U-tubes. Air pressure, mercury barometer. Surface area and support, ants and elephants.

4. Radiant energy.

COMMENT

Energy exchange is a very important aspect of physical science and this course must provide and opportunity for discussion of energy. As the time is short it has been to select only one aspect of energy for detailed study after preliminary discussion and demonstration has given a broad picture of the possible range of energy study.

Since it has been usual to introduce some heat and light into science courses for 11 and 12 year olds, radiant energy has been chosen as suitable as a form of energy for study in this course. Attention has been paid in the study of heat to the quantitative aspects of heat gain and heat loss. In the light section the main emphasis is on the wave nature of light but some work on lenses has been included.

SYLLABUS

Forms of energy. Sources of energy. Energy exchange.

Heat as a form of energy, temperature measurements, quantity of heat, temperature rise dependent on mass and nature of substance. Graphs of rates of heating and rates of cooling. Significance of the high specific heat of water. Absorption and emission of heat.

Change of state, quantity of heat needed to melt ice, to boil water. The significance of the high latent heats of water.

Light as a wave motion. Intensity measured by light meters. Greenhouse effect.

Refraction of light by water and glass. Snell's law. Dispersion by a prism and by a diffraction grating. Transparent, coloured, and opaque objects.

Lenses. Real images. Focal lengths. Object/image distances. Magnification, similar triangles. Minimum distance for image.

## B. THEORIES AND MODELS. MOLECULES AND ATOMS

Section A has been concerned with observation, recording, and measurement. This section moves the student forward to consider ideas which are more abstract and by use of more quantitative examination of physical and chemical phenomena introduces him to some theories and models in the physical world. Three sections have been chosen from the many which could have been selected.

1. The particulate nature of matter is approached by a study of crystals and of the kinetic theory of matter.

2. The nature of chemical reactions is studied by examining some elementary chemical laws and by investigation of quantitative relationships observable during chemical changes.

3. The electrical nature of atoms is developed through electrostatics, electric currents, electrolysis, and simple radioactive phenomena.

The mathematical practices studied in this section include some new graphical work, for example Boyle's law leads to hyperbola, more proportion is needed in the work with standard solutions, and the introduction of statistical methods occurs when radioactive measurements are taken.

In this section we hope to show the students that science is not simply concerned with collecting information but is involved in discussing and modifying theories and pictures in the light of new evidence.

SYLLABUS

6. Particulate nature of matter.

Dilution experiments with fluorescein. Diffusion of gases, liquids, and solids. Spread of perfume.

Crystals. Rapid and slow growth of alum, copper sulphate, sodium chloride. Salol crystal growth under the microscope. Crystal models of common structures.

Kinetic theory. 2D and 3D models. Brownian motion of smoke particles in air. Boyle's law (hyperbolic graph). Charles's law (linear graph). Absolute zero.

Molecule size. Surface tension. Oil film thickness.

7. Chemical reactions.

Law of constant chemical composition. Electrolysis of water, preparation of copper sulphide, displacement of silver by copper. Equivalent weights.

Standard solutions. Vitamin C in lemon juice. Energy changes between hydrochloric acid and sodium hydroxide solutions. Acid/alkali titration.

8. Electrical nature of atoms.

Electrostatics. Frictional electricity. Electric charges. Positive and negative charges.

Electric current. Simple circuits. Current, potential and resistance measurements. Meters.

Electrolysis. Faraday's first law from gas voltameter, second law from water, copper and silver voltameters.

Radioactivity. Expansion and diffusion cloud chambers. Spark counter. Absorption by air, paper, aluminium, and lead. Half life analogue with ball bearings (exponential curve). Radioactive counting with scaler and sealed source.

Elementary statistics applied to radioactive counting and to sampling. Mean, mode, mediam. Normal distribution. Standard deviation. Confidence distribution of t he mean.

## C. CHANGING PATTERN OF SCIENCE TEACHDNG

The aim of this section is to acquaint students with the proposals which have been made in recent years for changes in teaching methods and content for science teaching at all school levels.

Perhaps the best way of showing students what is meant by "Primary School Science" is to take them through some typical free ranging investigations, at their own level, in the way in which work is done in primary schools. Each student will be asked to prepare and carry out a personal investigation and the whole group will mount a final presentation. Books and films from official sources on primary school science will be discussed.

Much time could be devoted to discussion of the many curriculum development studies in science for 11 - 16 year old pupils which have been carried out in recent years, but this course will have time only for a lecture or two during which the main suggestions will be summarized, and a bibliography will be provided so that the students may pursue the discussions in their own time.

The course ends with discussion of the aims, problems, and programmes of school science for the middle years. At present, (1969), this is a field in which there is little experience on which to build since, in the past, very little attempt has been made to construct a bridge between the very different approaches to science teaching in primary and secondary schools. Clear thinking about principles is called for.

SYLLABUS

9. Primary school science.

Investigation work at the student level will be carried out within the pattern of primary school science.

Each student will carry out a personal investigation and the whole group will make a final presentation.

The following books will be referred to and students will be expected to study them in their own time:

Ministry of Education. Science in primary schools. H.M.S.O. 1961.

Nuffield Foundation. Junior science. Teachers' B ooks I and II. Animals and plants. Apparatus. Collins. 1967.

Association for Science Education. Science for primary schools. Books 1 - 4. Murray. 1967.

The following film will be shown and discussed.

"Into Tomorrow". Nuffield Foundation. 1967.

10. Secondary School Science.

A lecture will be given summarizing the main proposals which have been made in the U.S.A., in Europe, and in Britain, during the last ten years for changes in science teaching in schools with children over the age of eleven. The following books will be referred to and students will be expected to be familiar with them.

S.M.A. and A.I.I.M. Science in secondary schools. 1958.

Ministry of Education. Science in secondary schools. H .M.S.O. 1960.

P.S.S.C. Physics. Heath. 1965.

ChemStudy. Chemistry. Freeman. 1963.

S.M.A. and Nuffield Foundation. The teaching of modern physics. Murray. 1963.

Nuffield Foundation. Physics. Teachers' Guides, Guides to experiments. Questions. Longman/Penguin. 1966.

Nuffield Foundation. Chemistry. Sample scheme. Options. Longmans/Penguin. 1966.

O.E.C.D. Teaching physics today. 1965.

O.E.C.D. Chemistry today. 1963.

Schools Council. Working paper 1. Science for the young school lever. H.M.S.O. 1965.

Schools Council. Examinations bulletin No.8.

C.S.E. Experimental examination, Science. H.M.S.O. 1965.

A.S.E. Science in the introductory phase. Murray. 1967.

11. School science in the middle years.

Attempts will be made to arrive at basic principles upon which curricula in science for 9 - 13 year old children in comprehensive school systems may be built.

## CHAPTER ELEVEN

## THE BACHELOR OF EDUCATION COURSE

Earlier in this thesis the point was made that a small minority of College of Education students have chosen such a college even though they might well have been accepted for a university course, and there are other students who had more than minimum entry requirements for a university but were not accepted. The Bachelor of Education degree offers to such students an opportunity of working at an academic level beyond that of the Certificate students within the framework of a course designed for intending teachers.

The Bachelor of Education courses proposed by the different Institutes of Education vary considerably in structure and requirements. In some courses degree students follow the same main courses as the certificate students for three years and then have an additional year devoted solely to B.Ed. study. This scheme enables selection of degree students to be delayed till the third year. In other courses only one year of study is common to both degree and certificate students, while at Manchester and Nottingham degree students will have specialist work to do in all four years. The admission requirements for the different university Institutes also vary, some insisting on matriculation qualifications of two Advanced Level and five Ordinary Level passes, and individual subject departments often lay down particular course requirements. Most Institutes require of their degree students study in three subjects, one being Education and the other two normal Main Course subjects, though in some cases variations involving the substitution of two subsidiaries for one main subject have been introduced.

A College of Education main course department wishing to offer a Bachelor of Education course must first of all obtain the sponsorship of a department or faculty of the university of whose Institute of Education it is a member. For most subjects the appropriate department to approach is obvious, for instance for French, H istory, or science subjects like Physics or Chemistry. However, in the case of Environmental Science there may well be difficulty in finding a university faculty willing to accept the subject as being one which the department feels belongs to its field. In the University of Newcastle upon Tyne the responsibility for the Environmental Science course at Bachelor of Education level has been accepted by the Faculty of Agriculture, who very naturally have decided views on the nature and content of the syllabus, and on the standard they would expect from candidates accepted for the course.

In view of the variety of university and course requirements, and the fact that all Bachelor of Education syllabuses need to be compiled by consultation between a university department and a College of Education main course department, it would not be sensible, in this thesis, to discuss in detail a Bachelor of Education syllabus in Environmental Science. The discussion in this chapter will therefore be restricted to two aspects of the B.Ed. course, the differences that might be expected between the B.Ed. course and the Certificate courses, and the role which the Physical Sciences could play in the degree course

Degree candidates will normally have Advanced level qualifications in two or more science subjects, but as the Environmental Science course draws from students who have studied physics, chemistry, biology, botany, zoology, geography, geology, mathematics, and perhaps rural science, in school sixth forms, it must be realised that in some of these subjects the degree student will be less qualified and less knowledgable than some of his contemporary Certificate students. The B.Ed. degree course should not be so organised that any individual candidate is required to achieve a level of attainment higher than Certificate level in all sections of Environmental Science. There will need to be enough flexibility to allow students to choose those areas in which their more advanced work will be done, and this will probably be in those areas in which they are qualified at Advanced level. At the same time every opportunity should be given to a B.Ed. student who wishes to do his advanced work in areas of Environmental Science in which he was not previously qualified.

It may be argued that the range of environemntal sdience as outlined for the Certificate course is too broad for the more academic approach which the B.Ed. degree asks for, and that if the degree course were narrowed it would give more opportunity for greater depth of study. I think there is a valid point in this argument but I think it has to be considered together with two contrary arguments. One is that if the range of the syllabus is restricted the very nature of the environmental approach is being threatened, and the other is the practical point that since it is anticipated that the number of B.Ed. candidates will be small, science departments may find it desirable to have at least part of its teaching common to both certificate and degree courses. I think the best arrangement will be to have the degree and certificate students doing the same course during the first year, but in the second and third years the degree students will do more and more of their work separate from the certificate stddents in gradually narrowing fields of study until in the fourth year each student may well be doing most of his work on an individual basis with the advice of the appropriate tutors, the specialists in the disciplines in which the student has eventually settled.

Since the B.Ed student is asked, in most Institutes of Education, to study two main course subjects as well as Education, and since he has also the usual College of Education commitments in curriculum courses and teaching practice, those who are to devise the degree course in Environmental Science must not overload the degree syllabus by requiring a lot of extra factual information. It is important to remember that the B.Ed. course should give its students the opportunity to do some original and constructive thinking, to mount some well conceived and well designed investigations and to show tutors and examiners that they are capable of sustained purposeful thinking. If a packed syllabus requiring memorisation and factual recall is produced then a great opportunity will have been lost. The degree course should not, in general, add to the number of areas of work, but should extend, within these areas, the depth and detail of investigation.

With regard to the role which the Physical Sciences should be expected to play in the B.Ed. course, it is assumed that most, though not all, of our degree students in Environmental Science will have come to us with an Advanced level pass in Physics or in Chemistry, or in both, and it is the work that these students will do in Physical Sciences which is our concern now. It is necessary for us to remember that the degree for which these students are studying is B.Ed. and not B.Sc. and this means that while the science they study must be academically demanding it must be science best suited for those who are to be teachers and not professional physicists and chemists. We shall not, therefore, look to the pattern of university courses in Physics and Chemistry for our syllabuses but to the needs of our students as environmentalists and potential teachers.

Our degree students, having passed Physics or Chemistry at Advanced level, have reached a level of knowledge of the subject which is most probably beyond that which they will ever be called upon to teach, since sixth form teaching of these subjects is almost always done by science graduates, and provided what they have done has been understood, there will be little need for our course to have as one of its aims the communication of further factual information in Physical Sciences. The course will be required to provide students with facilities for examination and measurement of environmental factors with greater precision and sophistication than the certificate course. Environmental measurement is subject to variability from two sources, the differences inherent in the experimental units examined and the limitations of techniques and procedures carried out in environmental situations. These two sources of variability impose on the student exacting standards of scientific discipline, and the care and attention in the statistical processing of data on the one hand, and the improvement of techniques on the other can provide our good students with the necessary challenges in their science study.

The areas of Physical Science in which our degree students would probably work are those which have already been mentioned in the certificate main course, but we would expect that the degree student would deepen the study and extend it. For instance, in the section on radiated energy, one might expect to see some emphasis on black body conditions, on the biological, chemical, and physical examination of the effects of ultra violet radiation, and in connection with measurements of light, instruments to measure the duration of sunlight and the intensity of direct and relected light would appear. In this connection the use of light meters as "black boxes" would not longer be sufficient and one would expect study of photovoltaic, photoemissive, and photoconductive phenomena. Similarly while some work on radioactivity will be done by all students, the degree students should study and practise methods used to estimate the age of rocks, the use of carbon 14 in dating, andthe use of radioisotopes as tracers.

Elementary chromatography and simple food tests have been included in the certificate main course but the B.Ed. course should require students to use more exacting methods of chromatography and electrophoresis in the analysis of more complex materials, in the course of extending their biochemical work into proteins, enzymes, and hormones. A strengthening of the background of the practices and principles of organic chemistry should be added for better understanding of the significance of the biochemical changes studied.

The initial study of chemical reactions should be extended to include quantitative work on chemical equilibrium and the factors which affect the rates of chemical reaction, and the colligative properties will reqüire more detailed attention.

In considering the properties of materials the B.Ed. student should include, in relation to liquids, phenomena of viscosity, streamline and turbulent flow, and in relation to solids he should investigate magnetic and electrical properties, when, for instance, semi-conductors would engage his attention.

These examples serve to show that those areas of Physical Science in the Environmental Science main course which have been selected for study by certificate students will also provide plenty of scope for the better qualified students wishing to proceed to the Bachelor of Education. It would, at this stage, be of little value to pursue discussion of the B.Ed syllabus into any greater detail.

CHAPTER TWELVE

TEACHING METHODS AND AIDS

The ages of students in Colleges of Education are those of university undergraduates, so in examining suitable teaching methods for our students it is convenient to consider some of the conclusions reached recently about how teaching should be carried out in universities. In the Report of the Committee on University Teaching Methods - the Hale report - (+ 94), published by the University Grants Committee in 1964, the teaching methods considered were lectures, seminars, tutorials, and practical classes. The nature of the lecture is clearly defined. It is a continuous exposition, free from interruption and questioning, though it may be followed by discussion. University authorities reporting to the Committee held that the advantages of the lecture were that it could be better thought out and prepared than replies given impromptu in a discussion, that it could cover more ground ina given time than a discussion could, and that, because it is as easy to lecture to fifty people as five, it is more economical with respect to staff time. Some university students' opinion, however, criticised the lecture because it was a one way process and because many lectures were too fast, too difficult, or too poor in quality. The other main criticisms of lectures are that there is no method of ensuring that students are making any mental effort during lectures, and that, in themselves, lectures provide no response or participation whereby the lecturers can judge success. The Report distinguishes between two types of lecture, one given to provide a framework to help the student to select profitably the reading he will do in the topic under discussion, and the advanced type used to give detailed information not readily available in books.

On the question of practical work the Report points out the great variety of forms in which practical classes are conducted, but it is clear that in all cases the lecture and the practical class are considered to be separate in time, place, and usually content. It is pointed out that a very economical type of practical class is one where a number of different experiments remain set up in a laboratory with complete instructions for the successful operation by individual students, and where the timetable is arranged so that several groups of students occupy the laboratory in fairly rapid succession. Demonstrators are available to help students. This method of conducting practical classes is totally unsuited to the needs of an Environmental Science department in a College of Education. Throughout this thesis stress has been laid upon the need for the students' work to be of an investigational nature, so that the students may learn as much as possible directly, by posing and solving problems which arise from directed observation. While it is true that Part Two of the Main Course syllabus, designed to enable students to acquire information, is largely composed of traditional enquiries, it is not intended that the experiments should be decided for the student or prepared for him with accompanying comprehensive instructions. Where particular pieces of apparatus need to be used, for instance a spectrometer, it is of course necessary that complete instructions on its operation should be given to the student, but otherwise it is hoped to give the student the mimimum rather than the maximum direction in connection with the investigation he is to carry out. Experience with these students has shown that they display considerably greater interest in and derive considerably more benefit from practical work which they do as part of an investigation no matter how simple it may be, than they do from working through a series of unrelated practical exercises.

Sharp distinction between lecture and practical class should not exist, I think, in a College of Education science cuurse. The students there have not as much maturity or confidence as university students nor are they able to select their reading as critically. Moreover, I think that many of the students in Colleges of Education benefit more from an empirical approach to the learning of science than from a formal or logical approach. I feel that while from time to time the set lecture, particularly of the first type distinguished above which sets the structure of a topic has its place, the most suitable form of teaching consists of sessions in which the investigation and the instruction are interwoven, where the practical work is an essential part of the learning process and where the tutor injects the necessary information and advice at appropraiet times. In other words the classes are much more like those found in schools rather than in the pattern of the universities. In teaching this way the practical work done by the students, the instruction given by the tutor, and the discussion between tutor and students are all integrated in time, whereas when lectures and practical classes are separate they can very easily get out of step. The limitation placed on this method of teaching is in the number of students in each class. While university lectures to forty or fifty science students by one lecturer are not uncommon (+94, p.54) this number would be far too large for one tutor to handle by the method I suggest.

There are two main solutions to the problem of numbers, one is for a tutor to take each topic more than once with groups of convenient size, and the other is to provide a team of two or more tutors for the large group. This large group, with its team of teachers, can of course only operate if there is a large enough practical room or laboratory in which to work. The role of the tutors in this situation is not the same as that of demonstrators in university practical sessions, since the classes in the College of Education, of the kind I propose, also serve the purpose of informing and building up the content of the subject. This is team teaching, not just supporting.

Apart from the possible desirability of team teaching because of student numbers it has a place in science teaching and particularly in an Environmental Science department, since much of the work done here spans normal science subject divisions and the presence of tutors of different specialist disciplines is of great advantage, and also because the extremely wide variety of previous background of the students in any given topic calls for instruction and investigation at different levels of sophistication simultaneously. I think that perhapsthe greatest advantage of team teaching in responsibility for the rest of the group, and the other gain I have found is in the building up of a very strong departmental bond between tutors themselves and between tutors and students. Most teachers spend their entire teaching hours separated from their colleagues whom they rarely, if ever, see in action, and only by casual remarks or by dubious report do they gain any information about the climate that exists in the classrooms or laboratories of other teachers, and I feel that this is unfortunate.

The Hale report was in favour of students taking notes during lectures, (+94,p.58), but not in favour of the notes being inspected by the staff. On the matter of hand-outs being provided by the lecturer for the student, the report gave several conflicting university opinions, for instance one which said that a lectures summary should be given to relieve students from note taking so that they could give their whole attention to the lecture, and another which said that students do not attend lectures if they know they will receive a detailed summary. Some authorities, such as L.S.Powell, (+74,p.3), are of the opinion that all lectures, whether to be followed by a seminar or not, should end with a hand-out of a summary.

In the situation of the combined Lecture/practical session which I suggest as the basis for our teaching, attendance is not affected by giving a summary, but the summary prepared beforehand, does not always accurately represent what is achieved on a particular occasion. Certainly in these sessions the students will have to make notes, at least of their own work. It seems then that our policy is a compromise in which some individual student' notes and some notes and data provided by the lecturer together contribute to the students' files.

All commentators and most students whose opinions have been recorded, (94,p.127), agree that discussion groups, in the form of tutorials of not more than four students or seminars of from four to twelve students, play a vital part in university life, and these meetings are also essential to our College of Education students. The two main reasons given for the importance of these activities are, one that students are given guidance at regular and frequent intervals in their private studies, the other that they enable tutors to judge the effort a student is putting into his work and the progress he is making. The H ale report draws a distinction in emphasis between seminars and tutorials, the former being, it says, subject-centred, and the latter student-centred. The seminar should provide an opportunity for a small number of people to discuss a topic in greater detail than was possible in a full class situation, and a tutorial should allow each individual to claim some time for his own personal questions and enthusiasms. Ideally the tutorial would be an individual personal interview, but very rarely will this be a viable proposition. The H ale report was very strongly of t he opinion, and it is shared by many other authorities, that discussion periods will be beneficial to the students only if they have done private study work on the topic for discussion, and it advocates that some at least of this should be written work, handed in and scrutinised by the tutor before the meeting, and discussed with the students at the meeting.

No mention is made in the Hale report of field studies, but it is obvious that in our course of Environmental Science all the facilities for work in the field will have to be used to the best advantage. There will be four main types of activities of this nature; individual or group work in or around t he college during normal main course or curriculum course time; half day or whole day excursions to specialised environments such as seashores, marshland or forests; extended periods of study over weekends or whole weeks at field study centres equipped with the necessary facilities for surveys and investigations of a continuous nature; and visits to sources of information and interest such as farms, museums, quarries, and the like. Due consideration should be given to the frequency and variety of these activities during the course.

It is common practice in universities and colleges to require each student to engage himself, over an extended period of time, in a personal project of private research. While it is essential that every student should become involved in some form of individual research, there is a danger that undue emphasis is placed upon this type of project as examination material. While very good work is often done in this way and this should be taken into consideration for student assessment, the place of the personal project in the whole scheme should be clearly defined and a disproportionate amount of time should not be spent on it. This time, I suggest, should not be more than the equivalent of about two hours a week for three terms and should occur in the middle of the course, when the student has had enough time to acquire the necessary independence but before the proximity of final examinations becomes a disturbing influence on the value of the project.

The possibility of including programmed learning as one of our teaching methods has to be considered. The H andbook of Programmed Learning published by the University of Birmingham, (52,p.11), gives ten canons of a good programme and one of these is that readiness is the best predictor of successful learning not chronological or mental age and that remedial provision of readiness demands the repair of omissions due to absence, inattention or erroneous learning. Programmed learning, it is claimed, enables students to reach this point of readiness by active participation at their individual rates. Undoubtedly one of the major difficulties facing tutors in Environmental Science is the very wide variety of science backgrounds and intellectual ability to be found in students in the department. Any help which can be found to enable inexperienced students in their own time and at their own pace, topic by topic, to bring themselves near to the mean of the class would be welcomed. However, as these programmes would have to be constructed by the tutors themselves and as they would have little value outside their own department it is very doubtful whether the time involved in devising such programmes, and the Hale report estimates it to be of the order of one hundred hours preparation for one hour of programme, could ever be found. It is generally recognised that programme writing is justifiable in terms of time and money only if a large number of students can be reached. Unless cooperation between colleges teaching similar courses can be arranged it seems unlikely that programmes in any numbers will be available.

Turning from teaching methods to teaching aids, we are concerned in this thesis only with particular applications of teaching aids to courses of Environmental Science and discussion of the use of teaching aids in Colleges of Education or in education generally will not be pursued. Some of the emphases which I think should be placed on certain teaching aids for our courses are summarised below.

Photography is an essential tool for recording and for research in the science department and all students should be given the facilities for taking and processing black and white still pictures, both prints and slides. The value of personal pictures in amplifying notes and projects and for displays, when enlarged, in school and college, is considerable, and should be fully exploited. (+64). In many areas of biological and earth sciences, and in some of physical science, the addition of colour is at least desirable if not essential, but the difficulties of the high cost of colour printing and the need for projectors and blackout for colour transparencies have to be considered. Some students, at least, will wish to have colour printing facilities, but these would probably be more economically provided on a college basis rather than on a departmental basis.

The use of film in the science department must be considered under different headings. The commercially produced documentary film should not be used as a substitute for investigation and direct experience by the students, or for material which the tutor can handle as efficiently, but there are topics for which the documentary film is suitable, such as detailed microscope work needing technical skill, or work extending over a long period of time which can be compressed into a film lasting perhaps only half an hour, or for subjects of unusual occasions such as those taken on an antarctic expedition. There will be many topics lending themselves to film treatment which are not available from commercial sources and here staff of the department will need the cameras and ancillary equipment for the preparation of appropriate films. For example, while students should be given the opportunity to make educational science visits, there will be a limit to the number of excursions any one group of students can make, and films made by the department of visits could extend the range of experience. Students should also be given the opportunity of making films in connection with their own work.

The value of Educational Television (etv) and radio from prepared B.B.C. and I.T.V. programmes lies chiefly in the inspiration and stimulus which an excellent lesson by a distinguished teacher can supply, and in the ability to provide material from unusual places and occasions. The only advantage peculiar to a science department in having closed circuit television (cctv) seems to be for simultaneous viewing by a large group of people of pieces of apparatus normally only seen by one individual. Examples of this are microscopy, insect behaviour, small scale physics apparatus such as Millikan's, and demonstrations of manipulative skill such as dissecting. The dangers in the introduction of either etv or cctv are the possible lapse into passive viewing and the distraction into the mechanics of the tv medium. The cost in terms of money and staff for cctv seems high for the advantages gained in the context of a science department in a College of Education having its own equipment, but there is undoubted advantage in being able to use, from time to time, cctv apparatus provided on a college basis.

It is essential that students intending to be science teachers should be given every possible opportunity and facility to work with the large variety of constructional materials which they will need in schools, traditional materials, wood,,metal, glass, card and paper, and synthetic materials, polythene, polystyrene, perspex, formica, and the variety of adhesives now available. The creative satisfaction of useful scientific model making should be enjoyed and encouraged.

The many other audio and visual aids, such as overhead projectors, tape recorders, and transparency projectors, and the teaching equipment particularly associated with science departments, such as microprojectors, oscilloscopes, and signal generators, have their own specialist literature and will not be discussed here, though of course they would be expected to be found in use in our science courses.

CHAPTER THIRTEEN

CONCLUSION

The discussion in this thesis has led to the presentation of syllabuses for main course and curriculum course students and some suggestions for degree students. The next steps are to introduce these courses into a number of Colleges of Education, to test them out under working conditions, and then to modify them as required. Several difficulties in this process have to be overcome. A college principal and a department head have to be persuaded that there is enough merit in these syllabuses to introduce them to their students. At the present time (1969) the numbers of sixth form pupils taking science subjects is declining, while the number of places for science students in universities, polytechnics and technical colleges is increasing, and those in charge of science in the Colleges of Education may feel that the strengthening of traditional methods is needed to maintain the number of science students. I suggest, however, that now is the time to change to a more interesting and adventurous course which will attract more rather than less students.

Information about these new courses has to be circulated throughout the country so that as many pupils as possible will know what is being offered, and will not be dissuaded from considering the course because it has a title which is unfamiliar. In particular, attempt must be made to attract men students, who in the past have tended to congregate in the more specialised and conventional courses. I have already mentioned the quite widespread prejudice which exists against broadly based science courses, and it is to be hoped that it does not adversely affect recruiting to the Bachelor of Education course in Environmental Science.

Cooperation of education authorities will be needed to provide modifications to building plans, since the requirements of Environmental Science courses with respect to laboratories, working spaces, palnt and animal houses, and the like, are not the same as those of conventional courses. The considerably greater emphasis placed on outdoor and field work in these courses will involve requests for redistribution of college money so that more is available for travelling expenses and less for the usual manufactured laboratory apparatus. Cooperation from college authorities will also be required so that our students may travel away for week-end or week study courses in the field in environments different from that of the college, and Institutes of Education will be asked to consider yet another examination, perhaps of a type quite different from those set at present, and this will require time for consultation and discussion. University departments will be asked to take responsibility for Bachelor of Education courses in a subject which no university, at present, offers.

To set against these difficulties there are advantages in this proposed course. All science students in a year group will work together and this will provide a more congenial atmosphere in which to work than that which prevails in so many science courses in those Colleges of Education where only a handful of students make up a subject year group. The staff also will work together and should be able to rouse enthusiasm and gaeity as a team more easily than a tutor on his one could. The interest and concentration of the students are vital to success, and it should be easy to stimulate these in a course which presents new material in a new way. We hope our students will, in turn, transfer this interest to the children they will meet in schools.

APPENDIX

ENVIRONMENTAL SCIENCE MAIN COURSE SYLLABUS

PART ONE

1. Introduction to an environment.

1.1 General observation. Broad environmental factors. Comparison of different environments.

1.2 Directed observation of a microenvironment: soils, tree trunks, walls, nests, leaf litter, rock pools.

1.3 Isolation of and concentration upon an experimental unit. A single organism or inanimate object as the focus of attention.

1.4 Identification of environmental factors. Breaking down of generalised influences to specific identifiable and measurable factors.

2. General environments.

2.1 Natural environments.

Woodland, fresh water, seashore, chalkland, moorland.

Abiotic factors; radiant energy, temperature, light, ionizing radiations, water, atmosphere, wind, substrate, soil, gravity, pressure, sound, fire.

Biotic factors. The interaction of living organisms with other living organisms.

Effect of organisms on microenvironments through temperature, water, wind and light.

Modification by organisms of substrate, e.g. soil building.

2.2 Rural environments partly under the control of man. Abiotic and biotic factors as in 2.1 above. Factors introduced by man: soil tillage, irrigation and drainage, manures and fertilizers, crop fruit and grass planting, herbicides pesticides and insecticides, plant breeding, animal breeding, forestry, fisheries, intensive farming methods. Land utilisation and conservation.

2.3 Urban environments with plant or animal or inanimate object as the experimental unit. The control by man may be almost complete as in a greenhouse, partial as in a park, or not at all as on a wasteland or stone wall.

Domestic animals and pets.

2.4 The environment of man. Scientific aspects of man in an urban community.

Heat and light from the sun and from domestic supplies.

Clothing. Loss of heat by radiation and evaporation.

Shelter from cold, heat, wind, rain and snow.

Oxygen and water vapour in the air.

Energy loss. Breathing and muscular activity.

Water and food.

Waste. Refuse and sewage. Air and water pollution.

Disease, medicine, hygiene, cleanliness.

Radioactivity.

Smells and sounds. Communication. Noise.

Pain and the nervous system.

Sex.

3. Basic ecology.

3.1. Content of ecology; populations, communities, ecosystems, the biosphere. H omeostatic mechanisms.

3.2 Components of the ecosystem; abiotic materials, producers, consumers, decomposers. Food webs. Energy flow, biogeochemical cycles. Habitat and niche.

3.3 Interaction of organisms. Limiting factors.

3.4 Ecological regulation, succession, competition, equilibrium, predation, parasitism, saprophytism.

3.5 Town ecology. Trees, wasteland, city streets, walls and paving stones, parks and gardens, soils, lawns.

3.6 World ecosystems; grasslands, forests, tundra, deserts, seas, estuaries, rivers, lakes, marshes.

4. The growth of investigations.

The posing of questions and the organising of experimentation and investigation directed towards the solving of problems.

The beginnings of personal projects.

5. The collecting of data.

5.1 Sampling, surveying, recording.

5.2 Photography as a valuable tool. Film speeds, aperture, developing and printing.

5.3 Instruments, their use and their accuracy. Designing and making instruments.

5.4 Building up an experiments

6. The handling of data.

6.1. Fundamentals of statistics. Distribution, measures of dispersion, significance.

6.2 Presentation of findings.

6.3 Validity of conclusions.

7. Personal project.

Each student will carry out an original investigation and will present a dissertation on it.

PART TWO

1. The Sun.

1.1 Light.

CONTENT

Light sources; sun, artificial sources, filament discharge and fluorescent lamps.

Reflection, refraction, absorption of light. Colour of setting sun, rainbows, mirages.

Transparent, coloured and opaque objects.

Spectra; the sun, white lights, discharge lamps.

Light sensitive devices; photometers, phototransistors, photoemission, photoconduction.

Inverse quare law.

LEVEL ONE PRACTICAL

Examine the spectrum of sunlight with a prism.

Produce a pure spectrum of white light from a filament lamp and compare it with the solar spectrum.

Observe white light spectrum with a diffraction grating and compare it with a prism spectrum.

Observe the effect of coloured filters on a white light spectrum.

Compare the mixing of coloured lights with the mixing of coloured pigments.

Compare the emission spectra of neon, mercury, oxygen, nitrogen, hydrogen.

Compare the effects of light on the different silver halides.

LEVEL TWO PRACTICAL

Prepare blueprints with potassium ferricyanide and ferric ammonium citrate and investigate the effects of directed and reflected sunlight, of artificial lighting and of ultra violet light.

Compare the readings of different light meters with light of different colours.

Plot relationship between distance from light source and light meter reading. Find out if intensity response of meter is linear.

Compare the frequency response to light of the eye and of a barrier layer photocell using colour filters and a flicker photometer.

Use a spectrometer to measure the wavelength of the lines of the hydrogen spectrum.

Show the relationship between light intensity and depth for water in a lake.

1.2 Heat

CONTENT

Radiated heat; factors affecting absorption, transmission, emission.

Thermometers and thermometric scales.

Quantity of heat, joule and calorie, specific heat, calorific values.

Change of state, latent heats, volume changes.

Transfer of heat by conduction, convection and radiation.

LEVEL ONE PRACTICAL

Test the absorption of heat by the back of the hand (a) blackened, (b) metallised.

Compare the radiation of cans with different surfaces.

Examine the influence of slope, colour and texture on soil temperatures.

Compare the absorption by glass plates of heat from the sun, an electric heater and boiling water.

Observe the construction and use of all types of thermometers.

Using thin and heavy calorimeters, water, sea water, cooking oil, soil and crushed rock, find the specific heats of some natural substances.

Estimate the latent heats of fusion and evaporation of water by adding ice and by boiling off.

Construct cooling cuxves through the melting points of p-dichlorbenzene and paraffin wax.

Show the volume changes on the freezing of water and paraffin wax.

Compare the insulating properties of some common materials.

LEVEL TWO PRACTICAL

Show how the absorption of heat by a glass plate depends on the angle presented to the source.

Estimate absolute zero using a constant volume air thermometer.

Show the effect of pressure on the boiling point of water.

Show convection in a greenhouse by measuring temperature gradients.

Find the optimum distance between panes of glass in double glazing.

Compare the calorific values of various solid and liquid fuels.

Compare rates of evaporation of a variety of liquids using a microbalance.

Show the relationship between temperature and depth for water in a lake.

1.3 Wave motion.

CONTENT

Water waves, ripple tank.

Sound waves, pitch, loudness, timbre, speed, need for medium.

Light waves.

Wavelength, frequency, velocity.

Interference, diffraction. Diffraction grating.
Thin films.

Polarisation, double refraction, optical activity.

Electromagnetic spectrum, visible and invisible radiations.

Infra red, ultra violet, X rays, gamma, cosmic and radio waves.

LEVEL ONE PRACTICAL

Measure wavelength and frequency of plane and circular waves on a ripple tank.

Show reflection, refraction, interference and diffraction of water waves on a ripple tank.

Show the use of a stroboscope in observing wave motion.

Observe loop films of longitudinal and transverse wave motion.

Show that sound waves need a medium in which to travel.

Show interference of light with Young's slits and a festoon bulb, and with a sodium lamp and a slit.

Show interference with a thin film of oil and a sodium lamp.

Observe X ray photographs of human tissues.

LEVEL TWO PRACTICAL

Show interference of sound waves with a tuning fork.

Display musical notes and sound on a cathode ray oscilloscope.

Calculate the speed of sound by a simple direct method.

Estimate the wavelength limits of the visible spectrum with a diffraction grating.

Measure the distibution of energy in white light spectrum.

Show the diffraction of light with a straight edge and of sound with a hardboard sheet.

Show the effects of ultra violet and infra red radiation on photographic films.

Record the song of the blackbird and find frequency range using a cathode ray oscilloscope.

1.4 Ionizing radiations.

CONTENT

Electric charges, conductors and insulators.

Electroscopes, gold leaf, Braun and pulse.

Electric currents, electrons in metals, diodes.

Discharge in gases, X rays.

LEVEL ONE PRACTICAL

Investigate the properties of electric charges with suspended poystyrene balls.

Test frictional charges with gold leaf and Braun electroscopes.

Show the ionization of air by a flame and by a radioactive source.

Show ionization of air with a spark counter and a radioactive source.

LEVEL TWO PRACTICAL

Use a pulse electroscope to detect charges and to show ionization.

Show ionization of air with a Van de Graaf generator.

---

1.5 Radioactivity.

CONTENT

Detection of radioactivity; photography, spark counter, expansion and continuous cloud chambers, ionization chambers, pulse electroscope, Geiger Muller tubes for solids and liquids, scalers, ratemeters.

Radioactive decay. Half life.

Properties of alpha, beta and gamma rays. Absorption. Isotopes. Radioactive tracers. Radioactive dating.

Biological effects of radioactivity. Radiation hazards.

LEVELS ONE AND TWO PRACTICAL

Show detection of radioactivity with pulse electroscope, spark counter, expansion and Taylor cloud chambers.

Show range of alpha particles with Taylor cloud chamber and with spark counter.

Display alpha particle tracks on nuclear photographic plates.

Find background count with G.M. tube and scaler.

Compare effects of radioactive isotopes of radium, plutonium, strontium, and cobalt.

Show the absorption of gamma radiation by wood, brick, concrete, water and lead.

Identify alpha, beta, and gamma radiation from absorption curves.

Find the half life of thoron using a pulse electroscope.

Illustrate radioactive half life with a ball bearing analogue.

Use radioactive potassium for autoradiography in a leaf.

## 2. Chemical Energy

### 2.1 Chemical reactions.

CONTENT

Separation and identification of pure substances.

Types of chemical changes.

Acidity and alkalinity. pH. Indicators. Acids, bases and salts. Redox reactions.

Rate of reaction, catalysts, dynamic equilibrium.

Electrochemical series. Reactions of metals with water, acids, salt solutions.

Gram-atom and gram-formula. Standard solutions, titration.

Compounds of carbon; chain and ring compounds. Homologous series.

LEVEL ONE PRACTICAL

Extract sodium chloride from rock salt by crystallisation.

Prepare pure alum from the impure salt.

Extract solids from sea water.

Test for halides on salts obtained from sea water.

Carry out flame tests on salts of potassium, calcium, strontium, barium, lead, copper and sodium and on the solids obtained from sea water.

Compare water from sea, river, pond, rain and tap for dissolved solids.

Test for iron in sea water.

Separate the constituents of crude oil.

Investigate the effects on various indicators of some common substances, lemon juice, vinegar, stomach powder, gardener's lime, soap, and others.

Use universal indicator to follow pH changes when slaked lime is added to vinegar.

Prepare salts from acids and bases.

Examine the effect of dilution on pH.

Prepare an approximately normal solution of hydrochloric acid and standardise it against normal sodium carbonate.

Observe the reactions between zinc and copper sulphate and between zinc and copper and silver nitrate.

Show changes between iron(II) and iron(III).

Show that a selection of organic compounds all contain carbon and hydrogen.

Show the building up and breaking down of a large molecule compound - perspex.

LEVEL TWO PRACTICAL

Separate liquid mixtures by distillation, fractional distillation and steam distillation.

Separate metal cations by electrophoresis.

Separate halide ions by thin layer chromatography.

Separate volatile inflammable liquids, ether, benzene, carbon tetrachloride by gas chromatography.

Construct titration curves for acid/alkali reactions.

Construct and use a conductivity meter to investigate hydrogen ion concentration.

Determine the dissolved oxygen in water by Winkler's method.

Show that molten lead oxide is an electrical conductor.

Show the effect on metal corrosion of the presence of other metals.

Prepare ethyl alcohol by the fermentation of cane sugar with yeast.

Prepare methane from sodium acetate and sodium hydroxide.

Prepare benzene and investigate its reactions.

Determine the molecular formula of a hydrocarbon.

2.2 Atomic Theory.

CONTENTS

Particulate nature of matter and of electricity.

Faraday's laws of electrolysis.

Molecules and atoms. Molecular size.

Atomic and molecular weights. Atomic number, mass number. Protons, neutrons, electrons.

Chemical laws. Periodic table.

Hydrogen atom. Orbitals.

Other atoms; ionic bonding, ionization; covalent bonding; double bonds.

Molecular structures; compounds, network solids, ionic solids.

Allotropy, isomerism, polymerisation.

LEVEL ONE PRACTICAL

Show the diffusion of bromine in air and in vacuum.

Show the diffusion of liquids; sugar solution and copper sulphate solution.

Show the diffusion of solids; potassium dichromate in gelatin.

Show Faraday's laws of electrolysis.

Compare properties of the alkali metals.

Compare properties of the halogens.

LEVEL TWO PRACTICAL

Show Millikan's apparatus for demonstrating the atomicity of electric charges.

Show the discharge of electricity through air at low pressure.

Show the photoelectric effect with a zinc plate.

Identify sugars by optical rotation.

2.3 States of Matter. Molecular Structures.

CONTENT

Solids.

Crystals; growth, cleavage, isomorphism.

Double refraction and polarisation, poleroid.

Metals and non-metals.

Conductors and semiconductors, thermistor, diode, phototransistor.

Magnetism.

Stress and strain; rubber, copper; fatigue; adhesives.

Liquids. Molecular forces.

Surface effects; oil films, capillarity, evaporation, viscosity.

Solutions; solubility, depression of freezing point, heat of solution.

Colloids, emulsions, gels.

Osmosis.

Gases.

Kinetic theory of gases. Brownian motion.

Gas laws. Absolute zero.

LEVEL ONE PRACTICAL

Grow crystal of sodium thiosulphate quickly.

Grow crystals of alum slowly.

Watch growth of salol crystals under microscope.

Cleave calcite crystals.

Construct a chemical garden in sodium salicylate.

Show isomorphism with chrome alum and potash alum.

Observe double images produced by calcite.

Look at rock sections between polaroid sheets.

Measure forces needed to extend a rubber band and a copper wire to yield points.

Examine metals for fatigue after repeated bending.

Investigate a range of adhesives and discover for which materials they are best suited.

Find the thickness of a film of olive oil on water.

Find the relationship between the height of capillary rise and the diameter of the tube.

Find the maximum height to which water will rise up blotting paper.

Find the effects on the freezing point of dissolving salt in water in different concentrations.

Prepare gels of gelatin, starch and soap. Find if they liquify on warming or on diluting.

Compare colloids of prussian blue and ferric hydroxide.

Observe the effects of soap and teepol on emulsions of paraffin, linseed oil and cooking oil.

Observe the Brownian motion of smoke particles in air.

LEVEL TWO PRACTICAL

Examine the electric properties of a thermistor.

Examine the properties of a germanium wafer.

Find the coefficient of restitution of a table tennis ball on a wooden table.

Compare the viscosities of water, liquid paraffin, olive oil, cooking oil and glycerin, by dropping glass beads through these liquids in a burette.

Verify the gas laws, Boyle's, Charles's, and the Third law, with air in a capillary tube.

Calculate the velocity of sound in air using a resonance tube and show it to be consistent with adiabatic conditions.

3. The Cell.

3.1 Paramecium, a Single Cell Organism.

CONTENT

Study of the single cell organism, paramecium, as an example of animal behaviour.

Consider the procuring and digestion of food, the transport and assimilation of nutrients, respiration, gaseous exchange, excretion, coordination, reproduction and growth.

Consider the homeostatic mechanism of paramecium living in water.

LEVEL ONE PRACTICAL

Microscopic observation of the life cycle of paramecium.

3.2 Cell Mechanisms.

CONTENT

Cell structure, protoplasm, nucleus, cytoplasm, mitochondria, ribosomes, Golgi bodies, plastids, centriole, cell wall.

Cell dividion; mitosis, meiosis.

Differentiation of tissues.

Diffusion and heat exchange, gases and solutes.

Osmosis in plant and animal cells. Molar and molal solutions.

LEVEL TWO PRACTICAL

Examine microscopically a selection of sections of plant tissues and associate their structure and function. Examples are root, stem, leaf, epidermal hair, bulb leaf, star cell, egg cell.

Examine microscopically a selection of animal cells and relate their structure and function. Examples are mucous membrane, muscle, cartilage, bone, egg cells.

Use a polarizing microscope to measure the bifringence of the material of plant cell wall.

Using a copper ferrocyanide membrane in a porous pot compare osmotic pressures of a selection of molal solutions.

## 3.3 Cell Biochemistry.

CONTENT

Photosynthesis and respiration.

Limiting factors; light, water, carbon dioxide; chlorophyll.

Carbohydrates.

Hexose and pentose sugars, phosphate derivatives. Sucrose, glucose. Starch; hydrolysis. Inulin cellulose.

Pyruvic acid. Krebs cycle. Fermentation.

Lipids.

Fats, hydrolysis. Waxes. Phospholipids.

Nitrogen compounds.

Amino acids. Proteins; denaturation, separation. Enzymes. Nucleic acids; regulation of living processes.

LEVEL ONE PRACTICAL

Compare various methods of extracting green pigment from plants.

Separate and identify constituents of plant pigment by chromatography in spring, summer and autumn.

Observe the absorption spectrum of pigment extract.

Investigate the effect of intensity of light, the periodicity of light, colour of light and carbon dioxide on photosynthesis of Canadian ponweed.

Use Benedict's test on glucose, fructose and sucrose.

Test for starch with iodine.

Carry out solubility tests on animal fats.

Carry out Millon, biuret, ninhydrin and xanthoproteic tests for proteins.

LEVEL TWO PRACTICAL

Seaparate sugars by chromatography.

Saponify a lipid and test for glycerol.

Test for fats with osmic acid.

Carry out the Sorensen test for amino acids.

Separate amino acids by two way chromatography.

Separate and identify proteins by chromatography.

3.4 Genetics.

CONTENT

Heredity and environment.

Mendelism; law of segregation, law of recombination, dominance.

Chromosomes in heredity; single trait and double trait inheritence; continuous variation.

Sex chromosomes; sex determination, sex linkage, linkage and crossover.

Chemical nature of genes. DNA and RNA. The genetic code.

Plant and animal breeding.

Human genetics.

LEVEL ONE AND TWO PRACTICAL

Raise seedlings from all the seeds of one apple and examine for phenotypic variation.

Compare genotype and phenotype influence in seedlings of Pelargonium zonale.

Carry out hybridization experiments with seeds of Antirrhinum majus.

Carry out breeding experiments with Drosophila melanogaster.

Try to obtain slides of chromosomes in tradescantia flower buds and fruit fly salivery glands.

Trace pedigree tables of families showing colour blindness, baldness, deafness.

Compare fingerprints within families and between families.

Compare class frequencies of blood groups A, B, AB, O with English population frequency.

4. Muticellular Organisms.

4.1 Plants.

CONTENT

Plants of the environment.

Roots, stems, leaves; anatomy and function.

Nutrition; absorption, transport, assimilation and storage of food.

Nitrogen cycle.

Photosynthesis. Influence of different factors. Leaf structure. Respiration.

Transpiration. Root pressure.

Tropisms; phototropism, geotropism, hydrotropism, thigmatropism, thermotropism, chemotropism.

Sexual reproduction; flowers, fruits and seeds.

Annuals, biennials, perennials.

Asexual reproduction; vegetative reproduction, gemmatiom, fission, spores.

Identification and classification of plants, with some examples.

Representative selection for more detailed study; algae, fungus, moss, fern, conifer, monocotyledon, dicotyledon.

LEVEL ONE PRACTICAL

Compile a simple classification key for the common local wild plants.

Examine and identify the parts of plants.

Observe growth and development of root system of a radish.

Grow plants with different root systems.

Show the colouring of leaves of carnations when roots are put in coloured water.

Test the strengths of various root systems.

Examine the external structure of a dicotyledon stem.

Examine the internal structure of sections of dicotyledon and monocotyledon stems.

Classify different types of stems observed.

Show conducting tissues of celery stem with coloured liquid.

Classify different types of leaves.

Show the passage of air through leaves.

Examine microscopically leaf cells.

Measure the rate of transpiration of a potted plant under different conditions.

Show carbon dioxide to be a product of respiration of a plant kept in the dark.

Demonstrate plant tropic responses to light, gravity, water, heat, touch.

Examine the parts of a flower, and classify different types of flowers.

Examine ovaries of flowers at different stages of development.

Collect and classify a variety of fruits.

Collect and examine microscopically algae and investigate factors controlling growth and reproduction.

Collect and examine varieties of seaweed. Dry and burn and find which varieties contain ~~seaweed~~ iodine.

Investigate the conditions needed to prepare and control a variety of bacteria cultures in nutrient agar.

Investigate the conditions for the growth and control of fungi. Classify the various types.

Examine the reproduction of yeast by budding.

Grow a moss or a fern and follow its life cycle.

Examine the Pinus sylvestris as a n example of a gymnosperm.

LEVELTWO PRACTICAL

Measure strength of stems in resisting bending and relate to plant size.

Compare growths of a plant in balanced nutrient solutions and note symptoms of nutrient deficiency.

Find quantitative relationships between mineral supply and plant growth.

Investigate the effects of girdles at different points on the growth of a fruit tree.

Measure translatory losses and gains in a tomato plant.

Use radioactive potassium as a transport tracer.

Measure root pressure by the height of a water column

Examine the causes of the spiralling of plants.

Trace the life cycle of a typical annual, biennial and perennial.

Examine the effects of radioactive irradiation on seed germination.

Prepare Bacillus subtilis from a hay infusion and examine microscopically.

Examine microscopically the symbiotic relationship of algae and fungus in lichens.

4.2 Animals.

CONTENT

Natural environments.

Animals in the soil.

Animals in the air. Birds, insects; capture and marking.

Animals in pond water; capture.

Animals of the seashore; marking.

Setting up and maintaining animal environments.

Ponds and aquaria; viverium; beehive; cages for birds, insects and mammals; poultry houses.

Animal study

Differences between plants and animals.

Classifying and naming animals.

The ten commonest phyla with some examples in each.

Particular animals selected for study in some detail; locust, frog, earthworm, snail, spider, dogfish, snake, finch, rabbit.

Particular animal features for study in some detail; digestion in hydra, earthworm and bird; locomotion in animals by flagella, pseudopodia, cilia, jet, contraction, undulation, jumping, walking, running, swimming, flying; reproduction, asexually, sexually.

LEVEL ONE PRACTICAL

Make a box for soil animals. Examine the behaviour of the animals under varying conditions.

Prepare a simple classification key for the soil animals.

Practice techniques of capture, mark and recapture of insects,fish and small mammals.

Build a freshwater pond of different levels and stock with suitable plants and a selection of water beetles, water fleas, water boatmen, flatworms, water snails, hydra and water worms.

Observe predator/prey relationships and life cycles under varying conditions.

Set up an indoor freshwater tropical aquarium and stock with suitable aquatic plants and a selection of guppie, mollie, platy, zebra fish, Provide dry and live food. Observe cyclic patterns of behaviour.

Set up a viverium for amphibia and stock with frog and toad spawn. Observe life cycles of the amphibia.

Set up and stock a cage of locusts and observe them as examples of insects with incomplete metamorphosis.

Dissect a dogfish and examine anatomical and physiological details.

Dissect a rabbit and examine details of its digestive and reproductive systems.

Compare asexual methods of reproduction in hydra and algae.

Compare sexual methods of reproduction in hydra, fish, frog, earthworm, insect, bird, rabbit.

LEVEL TWO PRACTICAL

Set up and maintain a hive of bees; study it as an example of a community of social animals.

Using an incubator with hen's eggs, test fertility of eggs by candling and observe the embryo at different stages of development by opening eggs.

Observe the effect of varying environmental factors on egg laying of poultry.

Relate the quantity of food consumed with body weight increase with cage birds, gerbils, and rabbits.

Investigate the effect on animal behaviour of change in environmental factors.

Calculate the efficiency of cages and houses with respect to heat loss.

Compare methods of locomotion in euglena, amoeba, proteus, paramecium, jellyfish, earthworm, snake, locust, rabbit, fish and bird.

4.3 Man.

CONTENT

Science of man responding to his physical environment.

Skin, hair, perspiration, heat conservation.

Sight; eyes, defects, spectacles, binocular vision, colour blindness, persistence of vision.

Hearing; ears, frequency range, sensitivity, deafness, stereophony, balance and dizziness.

Touch; sensitivity to heat, cold, pain, pressure, electricity.

Smell and taste; individual variation, saturation, sweet and sour areas.

Respiration; relationships between breathing, heart beat, body temperature and muscular activity. Effect of ventilation and humidity.

Man's energy; work, fatigue, rest, sleep, food and digestion, food values, vitamins.

Nervous system; reflex actions, conditioned reflexes, voluntary actions.

Ductless glands; hormones, insulin, thyroxin, adrenalin, sex hormones.

LEVELS ONE AND TWO PRACTICAL

Examine various human hairs and compare texture, colour and strength with cell structure.

Examine the effects of shampoos and hair dyes on human hairs.

Test eyes for short sight, long sight, astigmatism, lossof accommodation, colour blindness.

Set up three dimensional pictures and test for deficiencies in individuals.

Find maximum time for persistence of vision by flicker speed.

Show stroboscopic effect with ripple tank.

Test upper and lower limits of audible frequencies. Relate these to age.

Devise a reliable test of hearing sensitivity.

Demonstrate stereophony.

Find which area of the skin have maximum sensitivity to touch.

Find minimum voltage for skin sensitivity.

Test sense of smell with a variety of single smells, with two smells together, and after exposure to a smell for a long period.

Test reactions of heart beat and body temperature to hot and cold environments and to muscular activity.

Find the changes in body temperature over a period of twenty four hours.

Find reaction time with a dropping penny when fresh and when fatigued.

Find reaction time with a dropping penny without and with alcohol consumption.

5. Horticultural Science.

5.1 Propagation

CONTENT

Seeds, spores; germination.

Bulbs, corms, rhizomes, tubers.

Root dividing, layering, air layering, cutting, grafting, budding.

LEVELS ONE AND TWO PRACTICAL

Compare the germination of seeds under various conditions of temperature, moisture and light.

Determine the minimum, maximum and optimum temperatures for a specific seed germination.

Compare the germination of polyanthus seeds stratified with those not.

Compare the germination of bean seeds sown at different depths.

Collect spores from mushrooms and fern fronds and find the optimum conditions for their cultivation.

Grow plants from cut portions of potato, carrot, coleusstem, iris root, and narcissus bulb, partly submerges in water.

Grow begonia and sansevieria plants from a leaf in sand.

Compare the propagation by cuttings of hardwoods, blackcurrants, ribes and deutzia with softwoods, fuschia, tradescantia and chrysanthemum.

Compare propagation by layering of berberis and blackberry.

Propagate lupin by root clump division.

Show psopagation of Fatshedera by air layering.

Make a grafting and a budding on apple trees and compare the results of pairs similarly treated in previous years.

5.2 Cultivation.

CONTENT

Soil management.

Ploughing, hoeing, weeding, mulching.

Manures and fertilizers. Herbicides.

Plant treatment.

Pruning. Hormones. Photoperiodism. Pesticides.

LEVEL ONE PRACTICAL

Compare lettuce growth thinned and not thinned.

Compare lettuce growth weeded and not weeded.

Sow lettuce seeds at intervals of time and compare growths.

Compare growth of potatoes with and without farmyard manure.

Compare grass grown with and without sulphate of ammonia.

Identify weeds as annual, biennial and perennial.

Compare the efficiency of various weedkillers.

Compare severe and light winter pruning of apple trees.

LEVEL TWO PRACTICAL

Use indole acetic acid on bean seedlings to show its effect on phototropism.

Examine the effect of root forming hormones on the development of cuttings of fuschia and antirrhinum.

Compare the weights and seed content of tomato fruit yields from untreated plants and those treated with a fruit setting hormone.

Investigate the value of gibberellin for germination and growth of a variety of plants.

Carry out investigations on the effects of photoperiodism on chrysanthemum blooms.

Identify and remove plant pests and test efficiency of pesticides.

5.3 Greenhouse.

CONTENT

Consider the physical and biological environmental factors involved in the construction and maintenance of a heated greenhouse.

Insolation; location, aspect, shape, transparent material, shading, "greenhouse effect".

Heat loss; shelter from wind and frost, materials of structure, sealing of windows, ventilation, conduction through walls and floors.

Interior; colour, artificial heating, boilers, undersoil heaters, thermostats, humidity, fans, water tables, automatic sprays, carbon dioxide burners.

Edaphic factors; use of soil and other growing media, herbicides and insectidides, fertilizers, hormones.

LEVELS ONE AND TWO PRACTICAL

Record the temperature variations in an unheated greenhouse at different times of the year.

Devise and use instruments to control conditions of heat - light - humidity balance in the greenhouse.

Use the greenhouse to produce artificial environments in which plants with unusual botanical features can be grown. Some examples are:

Asplenium bulbiferum  Begonia semperflorens.
Billbergia nutens  Cissus antarctica.
Cyperus elaterium  Eucalyptus globulus
Hedera canariensis variegata  Impatiens balsamina
Linaria cymbalaria  Mimosa pudica
Nicotiana affinis  Pelargonium zonale
Schizanthus hybridus  Zebrina pendula
Sansevieria trifasciata laurentii

Follow the life cycle of plants grown from bulbs such as crocus, daffodil, hyacinth, snowdrop and tulip.

Form a desert garden of cacti and observe the behaviour of these plants towards water and temperature and compare this with other plants.

6. Lithosphere.

6.1 Materials.

CONTENT

Mineral identification.

Physical tests; colour, streak, lustre, crystal form, cleavage, hardness, specific gravity, magnetism, fluorescence, refractive index, radioactivity, X ray diffraction.

Chemical tests; acid reactions, molybdate reaction, borax bead, charcoal block, flame coloration.

Mineral classification. Some selected examples for more detailed study; quartz, feldspars, micas, metallic ores.

Characteristics of chief types of igneous, sedimentary and metamorphic rocks. Recognition and description of the commoner rocks.

LEVELS ONE AND TWO PRACTICAL

Grind down samples of different rocks and separate constituents. Examine microscopically.

Carry out physical tests on known minerals and then identify collected unknown minerals.

Carry out borax bead, charcoal block and flame colour tests on salts of copper, iron, cobalt, manganese, nickel, antimony, lead, cadmium, sodium and potassium, and use results to identify unknown minerals.

Examine examples of the chief crystallographic groups and compare with collected specimens.

Collect and identify a selection of igneous, metamorphic and sedimentary rocks.

Collect fossil samples.

6.2 Geological Processes.

CONTENT

Description of the earth's crust and interior.

Earth movements; diastrophism.

Rock deformation, folding, anticlines, synclines, joints, fissures. Faulting.

Earthquakes. Volcanism; gases and vapours, lava.

Initial landforms, mountains, plains, plateaux.

Age of rocks. Fossils.

LEVEL ONE PRACTICAL

Interpret local geological maps and check by visiting outcrops.

Carry out a traverse, surveying with compass and clinometer.

Trace and plot folds and faults.

Make stratified plasticene models of rock deformation.

Take photographs of rock features and display with geological maps.

Visit caves, quarries and cliff faces to examine exposures.

LEVEL TWO PRACTICAL

Measure the thickness, dip and strike of rock beds.

Find examples of cross beds and ripple marks.

Locate examples of preserved trees in bogs.

Visit a coal mine and examine underground structures.

6.3 Landscapes.

CONTENT

Weathering

Mechanical; frost, wind, temperature changes, plants and animals, water.

Chemical; carbonation, oxidation, hydration.

Speed of weathering; nature of rock, climate, topographical features.

Soil formation, leaching.

Erosion

Wind, water, waves and currents, rivers, glacial ice, ground water, gravity.

Landscape development; regional landscapes. Rock exposures. Evidence of rock activity. Results of weathering and erosion.

Land usage.

Factors of nature of rock, soil, land forms, climate.

Settlement. Use of local natural materials.

LEVEL ONE PRACTICAL

Investigate the effect of dripping water on a variety of rocks.

Investigate locally the weathering of bricks, stones and concrete.

Show the breaking of rocks by heat changes.

Show the breaking of rocks by freezing.

Find examples locally of weathering by wind.

Observe erosion caused by rivers.

Observe sea erosion.

Find locally evidence of glacial activity.

Find examples of the planting of grass to reduce wind erosion.

Find examples, locally, of trees planted as shelter belts.

Find a location where settlement changes can be related to landscape changes, e.g. the working out of a coal seam or the silting up of a river.

LEVEL TWO PRACTICAL

Investigate the effects on stones of lichens.

Investigate the effect of carbonic acid on rocks.

Show that limestone is dissolved by water.

Show the regelation of ice.

Relate bedrock, soil, climate and land usage.

## 6.4 Soil

CONTENT

Soil formation. Description and classification of soils. British soils. Effects of rocks and soils on landscapes. Soil testing.

Soil as an ecosystem.

Soil management. Manures and fertilizers. Compost, soil substitutes. Nitrogen fixing bacteria.

Soil conservation.

LEVEL ONE PRACTICAL

Examine a variety of soil profiles and take samples for physical and chemical investigation.

Collect samples of stream water during dry and wet weather. Allow to settle and compare.

Collect soil samples from a wide area and compare with geological map.

Collect soil samples and compare with vegetation.

Grow radish seeds in different types of soils maintained under the same conditions. Compare germination and plant growth.

Find the water content of different soil samples.

Find the maximum and minimum temperatures of soil at different depths over a period of time.

Find the humus content of different soils.

Compare the effects on sandy and clay soils of quicklime, slaked lime and gardener's lime.

Compare the properties of soil substitutes, hydroponics, vermiculite, peat and no-soil composts.

Make a garden compost and carry out physical and chemical tests as for soil during several stages of maturing.

LEVEL TWO PRACTICAL

Compare the several methods of measuring soil pH, papers, BDH kit, capillator, pH meter.

Find the effect of liming soil on its pH.

Carry out quantitative soil chemical tests for potassium, phosphorus, nitrate and ammonium.

Invetsigate the physical and chemical properties of fertilizers.

---

7. The H ydrosphere. Rivers and Seas.

CONTENT

Water Cycle.

Precipitation.

Hygroscopic, capillary and gravity water. Ground water. Water table. Run off water.

Evaporation, evapotranspiration.

Wells, springs, geysers. Lakes, swamps.

Sea Water.

Composition. Minerals from the sea.

Sea/atmosphere energy exchange.

Energy in sea waves.

Wind/sea energy exchange. Sea currents.

LEVELS ONE AND TWO PRACTICAL

Set up columns of beads of different sizes and find the ratios of capillary and gravity water. Find the porosity and permeability in each case.

Repeat as above with sand, loam and clay.

Collect and evaporate sea water. Identify dissolved material chemically.

Use Winkler's test for dissoled oxygen in water samples from a variety of sources.

Test water samples from different sources for radioactivity.

Test samples of water from various sources for pH with an accurate pH meter.

---

8. The Atmosphere.

8.1 Air.

CONTENT

Composition of the air. Carbon and nitrogen cycles.

Layers of the atmosphere. Temperature gradient; adiabatic changes.

Air pressure, barometers, baragraphs.

Absorption by the atmosphere of the sun's radiation; effects of latitude, land and water masses, ocean currents. Seasonal and diurnal effects.

Effect of the atmosphere on the condition of the surface of the earth.

Atmospheric circulation; effect of the earth's rotation. High altitude winds; local winds, land and sea breezes, mountain and valley breezes.

LEVELS ONE AND TWO PRACTICAL

Measure air pressure with mercury and aneroid barometers.

Find the weight of air by direct measurement.

Find the temperature of boiling water at pressures below and above atmospheric.

Show adiabatic expansion using Clement and Desorme's apparatus.

Compare distant radio reception quality at various times of the day. Locate radio stations on reception margin.

Observe temperature inversion in hollows and locate local frost pockets.

Compare day and night temperature variation on clear nights and cloudy nights.

Show the effect of aspect on soil temperature on a north-south soil bank.

Compare the temperature rises of water, soil, sand, and rock in radiated heat.

8.2 Water in the Atmosphere.

CONTENT

Humidity, absolute and relative; hygrometers, psychrometers, hair hygrometers, dew point hygrometers.

Clouds and fog. Types of clouds.

Precipitation. Rain, cloud seeding, drizzle, snow, sleet, hailstones.

Sea salt.

LEVELS ONE AND TWO PRACTICAL

Find the dew point with ice in a polished can.

Show development of fog in a Winchester bottle with clean air and with smoky air.

Show formation of frost and ice with a freezing mixture in a can.

Examine hailstones and snowflakes when they fall.

Compare values obtained for relative humidity from dew point reading with a psychrometer, from a hair hygrometer, with a wet and dry bulb thermometer, and by chemical analysis.

Identify cloud types from pictures.

Collect rain near the sea and test for salt.

8.3 Weather.

CONTENT

Air masses; stable, unstable, tropical, polar, continental, maritime.

Weather fronts; cold, warm, occluded.

Cyclones and anticyclones. Storms, hurricanes, tornadoes. Thunderstorms.

Meteorological instruments; thermometers, barometers, anemometers, radiosondes, weather satellites, radar.

Weather maps; isobars, Beaufort scale.

Microclimates; cities, hills and valleys, forest and open, lakes.

LEVELS ONE AND TWO PRACTICAL

Demonstrate adjustment of fluid masses in ~~a~~ large tanks.

Measure the rate of evaporation of water from a large flat pan. Relate this to temperature, humidity and wind speed.

Study weather maps for a seven day period and estimate weather conditions at a selected spot during that time. Compare with records of the actual weather.

Study the instruments used for weather forecasting and take readings with them; maximum and minimum thermometers, thermograph, hygrometers, psychrometer, Fortin and aneroid barometers, barograph, anemometer, wind vane, sunshine recorder, rain gauge.

9. Urban Man.

9.1 Power supplies.

Electricity

Electric fires, immersion heaters, storage heaters, infra red lamps.

Electric lighting; filament, gas discharge, fluorescent, ultra violet lamps.

Electricity supply; generating stations, distribution.

Simple electrical circuits, measuring instruments, electrical units.

Electromagnetism, alternating currents, transformers.

Fuels.

Coal, coke, coal gas.

Natural gas, propane, butane.

Paraffin, light oils heavy oils.

Nuclear power.

LEVEL ONE PRACTICAL

Visit an electricity generating station.

Investigate the heating, magnetic and chemical effects of simple circuits using a circuit board.

Measure currents and voltages in a variety of circuits using a circuit board.

Construct a resistor of known resistance with eureka wire.

Investigate electromagnetic phenomena with the

Worcester kit.

Investigate energy change from chemical to electrical in Leclanche, Daniell and dry cells.

Visit a coal mine and a gas works.

Investigate the burning of a candle.

Investigate the burning of town gas.

Investigate the burning of carbon compounds.

Investigate the effect of heat on wood.

Investigate the effect of heat on coal.

Investigate the operation of a paraffin pressure heater, e.g. a Primus stove or a Tilley lamp.

LEVEL TWO PRACTICAL

Use a cathode ray oscilloscope and transformer to examine the properties of alternating current.

Examine the phase relation ships between current and voltage in circuits containing resistance, capacitance and inductance.

Separate the constituents of petrol by fractional distillation.

9.2 Health.

CONTENT

Water

Sources of water for towns; rivers, lakes, wells, springs, rain water.

Purification of water; sedimentation, filtration, sterilization, distillation, electro-dialysis, reconstituting.

Hard and soft water; testing softness, ion exchange resins.

Milk.

Types; untreated, pasteurized, homogenized, sterilized, dried, skimmed, condensed, evaporated.

Tests for fats and proteins.

Food preservation

Effects of exposure, air, temperature changes, climates, seasons on food.

Effects of cooking on food.

Canning, bottling, freezing, salting, curing, pickling, dehydrating, chemical additives, irradiation.

Hygiene.

Viruses, bacteria, protozoa, fungi, animal parasites, flies, mosquitoes, fleas, lice, bed bugs.

Cleanliness, soap, soapless detergents.

Sewage and refuse disposal.

Antiseptics, disinfectants, insecticides.

LEVELS ONE AND TWO PRACTICAL

Examine tap water microscopically.

Distil some tap water and compare the taste with the original.

Compare samples of water from different sources tap, rain, stream, pond, sea, for hardness.

Visit town reservoir.

Compare hardness of water before and after using ion exchange resins.

Examine microscopically samples of untreated, pasteurized, homogenized and sterilized milk. Stain fat globules with Sudan IV.

Test milk samples with indicators for content of carbohydrate, sugar and protein.

Investigate the factors determining curd formation in milk.

Separate milk constituents by successive centrifuging.

Examine the effects of antiseptics on milk.

Heat milk samples to different temperatures and compare rates of souring.

Compare rates of deterioration of meat at room temperature, in a domestic refrigerator and in a deep freeze.

Compare the deterioration of eggs in air and in water glass.

Show the preservative value of sugar in fruit jams.

Compare the growth of bread mould in ordinary light and under ultra violet light.

Compare pickled onions with onions kept in water.

Show the killing of bacteria a nd the preserving of food by canning and bottling while hot.

Visit town sewage disposal unit.

Compare various soaps and detergents for efficiency.

Investigate the efficiency of various disinfectants.

Investigate the properties of insecticide aerosols.

Investigate the life cycles of domestic flies, flees, head lice.

10. ENERGY EXCHANGE

CONTENT

Forms of energy; chemical, foods, fuels, muscular energy; heat; radiation; electromagnetic, radioactive; kinetic, mechanical; potential, gravitational, strain; electrical.

Principle of conservation of energy.

Metric units of force, work and power. Collision, momentum. Newton's laws of motion.

Examples of energy exchange in nature; wind, movements of water and ice, freezing and melting, sun's radiation, earthquakes, volcanoes.

Energy trenfers within living structures; heterotropic cell systems, coupled reactions, DPN, TPN, ATP, ADP, glycolytic phase of respiration, biological oxidation, photosynthesis.

Examples of energy cycles in nature; carbon cycle, nitrogen cycle, hydrological cycle, phosphorus cycle, ornithine cycle.

Atomic energy as a special case of mass/energy exchange.

Entropy.

LEVEL ONE PRACTICAL

Show energy exchange in a large number of different ways. Some examples are given:

Electrical to chemical - charging accumulators.

Chemical to kinetic - motor car.

Potential (latent heat) to kinetic - steam engine driving wheel.

Potential (gravitational) to kinetic - water wheel.

Kinetic to electrical - wind driven generator.

Radiant to electrical - light meter.

Find relationship between electrical energy and heat energy with a Joule calorimeter.

Find relationship between kinetic energy (mechanical) and heat with a friction calorimeter.

Investigate a pulley system to show conservation of energy and frictional loss.

LEVEL TWO PRACTICAL

Find the calorific value of a fuel - petrol.

Find the heat of neutralization of normal acid and alkali solutions.

Find the heat of solution of ammonium chloride.

Find the e.m.f. of a copper/iron thermocouple.

- - - - - - - - - -

REFERENCES


1. Allen, G.E. Nature study in town schools for children under eight. Schools Nature Study Society. 1960.

2. Allen, Brown, Southam, and Tuke. Scientific interests in the primary school. National Froebel Foundation. 1958.

3. Association for Science Education. Science for primary schools. Parts 1,2,3,4. Murray. 1966.

4. Association for Science Education. Teaching science at the secondary stage. Murray. 1967.

5. Association for Science Education. Science in the introductory phase. Murray. 1967.

6. Association of Teachers in Colleges and Departments of Education. Science in the primary school. Murray. 1959.

7. Association of Teachers in Colleges and Departments of Education. Handbook on training for teachers. 4th. ed. Methuen. 1964.

8. British Association for the Advancement of Science. The place of science in primary education. British Association for the Advancement of Science. 1962.

9. Best, A.C. Physics in meteorology. Pitman. 1957.

10.. Brown, S.C., Clark, N., and Tiomino, J. Why teach physics? Massachusetts Institute of Technology Press for the International Union of Pure and Applied Physics. 1964.

11. Bruner, J.S. The process of education. Oxford University Press. 1960.

12. Calouste Gulbenkian Foundation. Enquiry into the suitability of the G.C.E. Advanced level syllabus in science as a preparation for direct entry into first degree courses in the Faculty of Science. University of Birmingham. 1960.

13. Carson, S.McB., and Colton, R.W. The teaching of rural science. Edward Arnold. 1962

14. Casey, E.J. Biophysics. Reinhold. 1962.

15. Catton, W.J. Physical methods in physiology. Pitman.

16. Central Advisory Council for Education (England). 15 to 18 (Crowther Report). H.M.S.O. 1963.

17. Central Advisory Council for Education (England). Half our Future (Newsom Report). H.M.S.O. 1963.

18. Central Advisory Council for Education (England). Children and their primary schools (Plowden Report). H.M.S.O. 1967.

19. Chetwynd, H.R. The comprehensive school; the story of Woodberry Down. Routledge and K.Paul. 1960.

20. Christopherson, D.G. The education of Britain's scientists who are teachers, in Education for Teaching, November 1964.

21. Cole, R. Comprehensive schools in action. Oldbourne. 1964.

22. Committee on Higher Education. Higher education (Robbins Report). H.M.S.O. 1963.

23. Comprehensive Schools Committee. Comprehensive education: secondary reorganisation in England and Wales. Survey No.1. Comprehensive Schools Committee. 1966.

24. Council for Cultural Cooperation. The contribution of audio-visual media to teacher training. Council of Europe, Strasbourg. 1965.

25. Council for Curriculum Reform. The content of education. University of London Press. 1945.

26. Education, Board of. Teachers and youth leaders (McNair Report). H.M.S.O. 1944.

27. Education, Ministry of. Pamphlet No.10. Local studies. H.M.S.O. 1948.

28. Education, Ministry of. Pamphlet No.35. Schools and the countryside. H.M.S.O. 1958.

29. Education, Ministry of. Pamphlet No.38. Science in secondary schools. H.M.S.O. 1960.

30. Education, Ministry of, Pamphlet No.42. Science in the primary school. H.M.S.O. 1961.

31. Education, Ministry of. Education in 1961. H.M.S.O. 1962.

32. Education, Ministry of. The work of the training colleges. Ministry of Education. 1963.

33. Education and Science, Department of. Statistics of education 1964. H.M.S.O. 1964.

34. Education and Science, Department of. Statistics of education 1966. H.M.S.O. 1966.

35. Edwards, R. The secondary technical school. University of London Press. 1960.

36. Enquiry into the flow of candidates in Science and Technology into Higher Education (Dainton Report). H.M.S.O. 1965.

37. Fisher, G.D., and Smyth, J. Teachers' book of nature study. Chambers. 1958.

38. Gates, D.M. Energy exchange in the biosphere. Harper. 1962.

39. Geographical Association. Local studies. Geographical Association. 1946.

40. Hartog, P.J., and Rhodes, E.C. Examination of examinations. Macmillan. 1935.

41. Hertfordshire County Council. Rural studies handbook. Arnold. 1966.

42. Humphreys, W.J. Physics of the air. Dover. 1964.

43. Incorporated Association of Assistant Masters. Teaching in comprehensive schools. Cambridge University Press. 1967.

44. James, E. An essay on the content of education. Harrap. 1949.

45. Jeffreys, M.V.C. Revolution in teacher training. Pitman. 1961.

46. Joint Matriculation Board. General Certificate of Education. Ordinary Level papers, 1966. Joint Matriculation Board. 1966.

47. Joint Matriculation Board. Examinations for the General Certificate of Education: statistics, 1966. Joint Matriculation Board. 1967.

48. Kerr, J.F. Practical work in school science. Leicester University Press. 1963.

49. Kilmister, C.W. The environment in modern physics. English Universities Press. 1965.

50. Kirby, K.S.N. Nature study for schools. Methuen. 1958.

51. Laybourn, K., and Bailey, C.H. Teaching science to the ordinary pupil. University of London Press. 1957.

52. Leith, G.O.M. A handbook of programmed learning. Educational Review. 1964.

53. Long, J.V. General and special studies in science, (in) Schools Council. Science in the sixth form. H.M.S.O. 1966.

54. Loughborough College of Education. Environmental studies syllabus. Unpublished.

55. Maddox, J. Nuffield physics, (in) Physics Education Vol.1, No.1. Institute of Physics. May 1966.

56. Mason and Langenheim, quoted p.5 in Gates, Energy exchange in the biosphere. Harper. 1962.

57. Miller, T.W.G. Values in the comprehensive school. Oliver and Boyd for University of Birmingham Institute of Education. 1961.

58. Morgan, R.H. Environmental biology. Pergamon.

59. National Advisory Council on the Training and Supply of Teachers. The future pattern of the education and training of teachers: eight report. H.M.S.O. 1962.

60. National Committee for Audio-visual Aids in Education. The overhead projector. N.C.A.V.A.E.

61. National Rural Studies Association. Rural studies. Pergamon. 1963.

62. Nature Conservancy Study Group. Science out of doors. Longmans Green. 1963.

63. New Educational Fellowship. Approaches to science in the primary school. Education Supply Association. 1960.

64. Newsome, J. Still phtography in education. National Committee for Audio-visual Aids in Education. 1966.

65. North East Junior Schools Association. Basic requirements of the junior school. University of London Press. 1949.

66. Nowell-Smith, P.H. Education in a university. Leicester University Press. 1958.

67. Nuffield Foundation. Progress report, 1964. Nuffield Foundation. 1964.

68. Nuffield Foundation. Physics: teachers' guide I. Longmans/Penguin. 1966.

69. Nuffield Foundation. Junior science. Collins. 1967.

70. Nuffield Foundation. Combined science. Unpublished.

71. Organisation for European Economic Cooperation. Policy for school science. O.E.E.C. 1961

72. Oxford Local Examinations. General Certficate of Education, 1969. Regulations and syllabuses. Oxford University Press. 1967.

73. Platt, R.B., and Griffiths, J. Environmental measurement and interpretation. Reinhold. 1964.

74. Powell, L.S. Lecturing to large groups. British Association for Commercial and Industrial Education. 1966.

75. Reeves (ed.). Eighteen plus. Faber and Faber. 1965.

76. Reigel, J.A. Energy, life and animal organisation. English Universities Press.

77. Richardson, J.A. Physics in botany. Pitman.. 1964.

78. Rogers, E.J. Teaching physics for the enquiring mind. Princeton University Press. 1963.

79. Schools Council. Working Paper 1: Science for the young school leaver. H.M.S.O. 1965.

80. Schools Council. Working paper 4. Science in the sixth form. H.M.S.O. 1967.

81. Schools Council. Field Report No.5. Science in the primary schools. H.M.S.O. 1967.

82. Science Masters' Association. Science for all - a plea for General Science (in) School Science Review, December 1920, Vol.II, No.6.

83. Science Masters' Association. Secondary modern science teaching. Murray. Vol.I, 1953. Vol.II, 1957.

84. Science Masters' Association and Incorporated Association of Assistant Masters. The teaching of science in secondary schools. Murray. 1958.

85. Science Masters' Association and Association of Women Science Teachers. Science and education: a policy statement. Murray. 1961.

86. Science Masters' Association and Association of Women Science Teachers. Science and education: physics for grammar schools. Murray. 1961.

87. Science Masters' Association, and Nuffield Foundation. The teaching of modern physics. Murray. 1963.

88. Secondary Schools Examination Council. Secondary school examinations other than the G.C.E.(Beloe Report). H.M.S.O. 1960.

89. Secondary Schools Examinations Council. Curriculum and examinations in secondary schools (Norwood Report). H.M.S.O. 1949.

90. Secondary Schools Examination Council. C.S.E: Introduction to objective examinations. H.M.S.O. 1964.

91. Snow, C.P. Two cultures and the scientific revolution. Cambridge University Press. 1959.

92. Spice, J.E. Structure and properties of matter, (in) Schools Council. Science in the sixth form. H.M.S.O. 1966.

93. Tricker, R.A.R. The contribution of science to education. Mills and Boon. 1967.

94. University Grants Committee. University teaching methods (Hale Report). H.M.S.O. 1964.

95. University Grants Committee. Audio-visual aids in higher scientific education (Brynmor Jones Report). H.M.S.O. 1965.

96. University of Bristol Institute of Education. Certificate of education and teaching certificate; handbook of regulations. University of Bristol. 1962.

97. University of Lancaster. Prospectus 1966-67. University of Lancaster. 1965.

98. University of London Institute of Education. Revised regulations and syllabuses for teachers' certificate. University of London. 1963.

99. University of Newcastle upon Tyne Faculty of Agriculture. Regulations. University of Newcastle upon Tyne. 1966.

100. University of Newcastle upon Tyne Institute of Education. Various authors: Teaching the Nuffield way. Journal of Newcastle upon Tyne Institute of Education, Vols. 85 to 95.

101. Wiseman, S. The efficiency of examinations, (in) Montgomery, R.J. Examinations and English education. Longmans. 1965.

ADDITIONAL BIBLIOGRAPHY

Allen, E.A. Professional training of teachers - a review of research (in) Educational Research No.5. 1962-3, p.200.

Association for Science Education. Science and general education. Murray. 1963.

Association of Teachers in Colleges and Departments of Education. The training of teachers in relation to the expansion of higher education. Association of Teachers in Colleges and Departments of Education. 1961.

Association of Teachers in Colleges and Departments of Education. Film and television in education for teaching. Association of Teachers in Colleges and Departments of Education. 1963.

Bloom, B.S. (ed) Taxonomy of educational objectives. David McKay, New York. 1956.

Brierley, J. (ed) Science in its context. Heinemann. 1964.

Browning, D.R. Science courses in "Wing" colleges of education (in) Education in Science No.16. Association for Science Education. February 1966.

Bureau of Current Affairs. Discussion method. Bureau of Current Affairs. 1950.

Daiches, D. The idea of a new university. Deutsch. 1964.

Dent, H.C. The training of teachers in the United Kingdom. Longmans for the British Council. 1962.

Education, Ministry of. Three year training for teachers. H.M.S.O. 1956.

Education, Ministry of. Pamphlet No.32: Training of teachers: suggestions for a three year college course. H.M.S.O. 1957.

Education, Ministry of. Report No.7: Training the teachers. H.M.S.O. 1964.

Efron, A. The teaching of physical sciences in the secondary schools of United States, France, and Russia. New York Teachers' Columbia, Columbia University.

Eyre, J.V. Henry Edward Armstrong. Butterwirth. 1958.

Fraser, D.M. Current curriculum studies in academic subjects. National Education Association, United States. 1962.

Gurney, P. Education and the training of teachers. Longmans. 1963.

Heath, R.W. New curricula. Harper and Row. 1964.

Humby, S.R., and James, E.J.F. Science and education. Cambridge University Press. 1942.

Isaacs, N. Early scientific trends in children. National Froebel Foundation. 1958.

Isaacs, S. Intellectual growth in young children. Routledge. 1930.

Johnstone, M.A. Science in the school garden. Macmillan.

Joint Committee for Science and Education. The supply of science teachers. H.M.S.O. 1962.

Kendall, M. Research into Higher Education. University of London. 1964.

Kneller, G.F. Higher learning in Britain. University of California Press. 1955.

Lamb, R.T.B. Aids to modern teaching; a short survey. Pitman. 1967.

Land, F.W. Recruits to teaching; a study of the attainments, qualifications, and attitudes of students entering training colleges. Liverpool University Press. 1960.

Langdon, E.M. Active methods of learning. National Froebel Foundation. 1951.

Lewis, D.G. Objectives in the teaching of science. (in) Educational Research, No.7, June 1965.

Lister, H. Effects of external examinations on the school. (in) Jeffery, G.B. External examinations in secondary schools. Harrap. 1958.

Lovell, K. Team teaching. University of Leeds Institute of Education. 1967.

MacLure, J.S. Eduwational documents; 1816 - 1963. Chapman Hall. 1965.

Mitchell, M, and Youngs, M. The roots of science. Blawkwell. 1965.

Montgomery, R.J. Examinations. Longmans. 1965.

National Advisory Council on the Training and Supply of Teachers. Scope and content of the three year course of teacher training. H.M.S.O. 1957.

National Committee for Audio-visual Aids in Education. The use of audio-visual aids in Colleges of Education. N.C.A.V.A.E. 1966.

National Froebel Foundation. Children learning through science. N.F.F. 1967.

National Science Teachers' Association - United States. New developments in elementary school science. N.S.T.A. 1963.

Nokes, M.C. Science in education. Macdonald. 1949.

Parry, J.P. The idea of a college of education. (in) Education for Teaching, February 1967 p.2.

Phillips, E.J., and McInnes, F.J.C. Exploration in the junior school. University of London Press. 1967.

Rogers, E.J. Physics for the inquiring mind. University of Princeton. 1962.

Schools Council. Examinations Bulletin No.8; C.S.E. Experimental examinations - science. H.M.S.O. 1966.

Schools Council. Examining at 16+. H.M.S.O. 1966.

Science Masters' Association. The teaching of General Science. Murray. 1950.

Science Masters' Association. Training of graduate science teachers. Murray. 1963.

Taylor, A. The place of chemistry in training college science, (in) Education in Chemistry, Vol.1, No.2. April, 1964, p.64-65.

Tempest, N.R. Some sources for the history of teacher training in England and Wales, (in) British Journal of Educational Studies, Vol,9, No1, November 1960.

Times Educational Supplement. Science at a new university. January 1963, p.84.

Turner, D.M. History of science teaching in England. Chapman and Hall. 1927.